Analysis of Engine Performance and Emission by Using Dual Bio Fuel

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ABSTRACT

The significance of this present investigation undertakes the feasibility study of a new combination of bio-fuels. For this rationale; the diesel engine operated with blends of Jatropha biodiesel, karanja biodiesel with a view to completely eliminate dependency on fossil fuel. Jatropha biodiesel (methyl ester) andkaranja biodiesel is a low and high viscosity fuels combination with comparable heating values to that of diesel; this makes conducive for its use in a diesel engine. Extensive experimental work is carried out on a Kirloskar make the single cylinder, natural aspired diesel engine to examine combustion performance and emission characteristics using Jatropha methyl ester with karanja methyl ester blends (dual fuel blends. Dual fuel blends are found to be the best substitute to conventional diesel fuel in all aspects such as performance and emissions. Further, BT 50 resulted at full load condition, reduction of 2.9%, 4.72%, 4.56%, 42.5% and 29.16% in the brake thermal efficiency, NOx, HC, CO and smoke respectively while CO2 emissions increase 10.7%.

I INTRODUCTION

India is also rich in renewable energy sources (solar, wind, hydro and bio-energy sources) but it has very less hydrocarbon reserve (0.4% of world's reserve). Given the limited domestic fossil fuel reserves, India depends on fossil fuel imports to meet its energy demands. the import of crude oil alone accounted for 31% of the country's total imports. So, it has ambitious plans to expand its renewable power industries.

Energy is an essential and vital input for economic activity. It is also the lifeline of modern societies. Building a strong base of energy resources is a pre requisite for sustainable economic and social development of a country. With increasing trend of motorization and industrialization, the world's energy demand is growing at a faster rate.

(a) **Properties of Jatropha oil -** Oil quality and consistency are important for producing biodiesel. The physical and chemical content of jatropha oil can be extremely variable. Oil characteristics appear to be influenced by environment and genetic interaction, as are seed size, weight and oil content. The maturity of the fruits also can affect the fatty acid composition of the oil, and processing and storage further affect oil quality .[1]

Table No. 1.1
Comparative characteristics of fossil diesel to pure jatropha oil [15]

Properties	Diesel	Oil of jatropha cruces seeds	Jatropha biodiesel
Density kg/l (15/40 °C)	0.84-0.85	0.91-0.92	.879
Cold solidifying point (°C)	-14.0	2.0	-3
Flash point (°C)	80	110-240	191
Cetane number	47.8	51.0	51–52
Sulphur (%)	1- 1.2	0.13	<.001

(b) Karanja Oil

Table No. 1.2

Comparison of fuel properties of karanja oil, karanja biodiesel and diesel [2]

Properties	**Unit**	**Karanja oil**	**Karanja biodiesel**	**Diesel**
Density@15^{0C}	gm/cc	0.9358	0.797	0.850
Viscosity@ 40^{0C}	cm^2/sec	38.8	7.0	**2.6**
Flash Point	0_C	212.0	97.8	70.0
Cetane Number		38.0	42.9	46
Sulphur Content	%	.025	–	–
Cloud point	0_C	2.0	-7	-16

II LITERATURE REVIEW

This part of the thesis will provide background in context of this research. A substantial amount of work has been done on the use of biodiesel as alternate fuels in compression ignition (CI) engines.

Ma and Hanna (1999)[3] described the transesterification, micro emulsions, thermal cracking (pyrolysis) and blending as different ways to lower the viscosity of the oil or fat. Although blending of oils with other solvents and micro emulsions of vegetable oils lowers the viscosity, engine performance problems, such as carbon deposit and lubricating oil contamination still exist.

Planning Commission of India (2003) [4] report of the committee on development of bio fuel, discussed the problems in using petroleum derived high speed diesel and characteristics, rationale, feasibility of producing biodiesel as substitute of petroleum diesel as well as target of bio-diesel production, specifications and quality standards for bio-fuels. While discussing the characteristics planning commission of India stated that bio-diesel had properties similar to petroleum diesel fuels.

Y.C. Sharma et al. (2007)[5] Development of biodiesel from karanja tree, mainly found in rural India has been investigated. The biodiesel was developed from oil expelled from the seeds of the tree. Molecular weight of the oil was determined and found to be 892.7. Both the acid as well as alkaline etherification was subsequently performed to get the final product. NaOH was found to be a better catalyst than KOH in terms of yield.

Plants absorb more carbon dioxide from the atmosphere during the process of photosynthesis than what they add to the atmosphere when used as fuel in compression ignition engine. Also use of biodiesel reduces wear of engine parts in comparison of diesel this happen by the property of lubricity of bio fuels.

Mathiyazhagan et al. (2011) [6] investigated on the non-edible oils as feed stocks for biodiesel production to reduce the cost of biodiesel. Normally alkali catalyzed method was followed for biodiesel production process. However the non-edible oils having high FFA content which is not suitable for normal transesterification process.

Pankaj B. Gavali et al. (2015)[7] Biomass derived vegetable oils are quite promising alternative fuels for agricultural diesel engines. Use of vegetable oils in diesel engines leads to slightly inferior performance and higher smoke emissions due to their high viscosity. The performance of vegetable oils can be improved by modifying them through the transesterification process.

AbsarLakdawala et al.(2016)[8]

Amongst all the experiments done for the alternative fuel, it is observed that biodiesel produced from renewable and domestic source represent a more sustainable source of energy and play a significant role in transport sector the major of research shown that emission of CO2 and CO reduced due to presence of O2 in biodiesel, presence of biodiesel enhance the proper combustion in the engine cylinder so exhaust comes out from the engine having low quantity of carbon oxides.

Hasimoglu et al. (2008) [9]stated that though esterifies fuels gives lower exhaust gas emissions and are biodegradable and renewable as compared to petroleum based diesel oil, viscosity and volatility problems still exist with these fuels. With the concept of a low heat rejection (LHR) engine (the engine that thermal barrier coating is applied is called low heat rejection (LHR) engine & the thermal barrier coated engine parts are piston, cylinder head, cylinder liners and exhaust valves)., the energy of bio-diesel can be released more efficiently thereby improving engine performance.

Zheng et al. (2008) [10]used soy, Canola and yellow grease derived neat biodiesel fuels and an ultra-low sulphur diesel fuel in the high load engine operating conditions with application of EGR. A naturally-aspirated four-stroke single-cylinder DI diesel engine was instrumented for the tests.

Sahoo and Das (2009) [11] compared the combustion characteristics of biodiesel fuel derived from jatropha, karanja, and polanga in a small engine at different load conditions. The authors reported that the pure polanga biodiesel was the optimum fuel blend as far as the peak cylinder pressure is concerned. However, they also reported that the ignition delay for pure Jatropha biodiesel was shorter than for diesel fuel, all of which are lower than diesel fuel.

Yanowitz and McCormick (2009) [12]experiments have been done on biodiesel and its blends to evaluate the combustion emissions like carbon monoxide (CO), carbon dioxide (CO2), particulate matter, sulphur oxides (SO2), oxides of nitrogen (NOx) and smoke are the main pollutants which are formed by biodiesel combustion.

Lin et al. (2009) [13] have examined eight different types of vegetable oil methyl ester in a single cylinder, 4-stroke, direct injection water cooled engine. They found higher range of bsfc from 9.45 to 14.65% for biodiesel than that of diesel fuel, which refers the same result obtained in case of LHV range from 12.9 to 16% of these vegetable oil methyl esters.

Haldar et al.(2009) [14]studied the performance and emission characteristics of Putranjivaroxburghii. In the Tropic of Cancer, these plants are abundantly available. The investigators observed that million tons of seeds of Putranjiva oil go a waste annually which villagers in remote areas can use in pure form or blended with diesel oil to operate engines for running irrigation pumps, grinding mills or straw choppers for cattle feed for shorter duration at the time of fuel crisis or emergency period.

Armas et al. (2010) [15] performed experiments on turbocharged diesel engine operated at 2400 rpm and 64 N m torque. The engine was tested with single and split (pilot and main) injections and without exhaust gas recirculation (EGR). Three fuels were used: an ultra low sulfur diesel fuel, a pure soybean methyl-ester and a Fisher–Tropsch fuel.

Panwar et al. (2010) [16] conducted a study for Performance evaluation of a diesel engine fuelled with methyl ester of castor seed oil. In this investigation, castor methyl ester (CME) was prepared by transesterification using potassium hydroxide (KOH) as catalyst and was used in four strokes, single cylinder variable compression ratio type diesel engine. Tests were carried out at a rated speed of 1500 rpm at different loads. Straight vegetable oils pose operational and durability problems when subjected to long term usages in diesel engines. These problems were attributed to high viscosity, low volatility and polyunsaturated character of vegetable oils.

Subbaiah et al. (2010) [17] investigated the performance and emission characteristics on a single cylinder diesel engine of conventional diesel, rice bran oil biodiesel, diesel and biodiesel blend and diesel-biodiesel-ethanol blends. He observed the bsfcof the biodiesel and all the other fuel blends was higher than that of the diesel fuel. The CO and hydrocarbon emissions (HC) of the biodiesel and all the other fuel blends were lower than that of the diesel fuel. The NOx emissions of the biodiesel and all the other fuel blends were low at lower loads and high at higher loads compared with the diesel fuel.

Yao et al. (2011)[18] analyzed reducing CO2 emissions from vehicles in China is crucial and will significantly alleviate the environmental burden of the Earth. Some promising technologies that make possible low-carbon vehicles are reviewed in this work, including electric vehicles, fuel cell vehicles, hybrid vehicles; bio fuels vehicles, other alternative fuel vehicles and conventional internal combustion engine vehicles with improvement.

Ghodasara and Rathore (2012) [19]conducted experiments on single cylinder, air cooled, constant speed direct injection diesel engine and developed and fitted EGR in engine. They concluded NOx emission decreases with increasing EGR rates but Smoke opacity, HC emissions increases with increase in EGR rates.

Roy (2013)[20] examined the emission of carbon monoxide (CO), hydrocarbon (HC), nitric oxide (NO), nitrogen dioxide (NO2), nitrogen oxides (NOx) and carbon dioxide (CO2) with pure and used canola biodiesel blends. CO and HC emissions from biodiesel–diesel blends were obtained significantly less than neat diesel fuel. The higher the biodiesel percentage in biodiesel–diesel blends, the lower the CO and HC emissions.

B. Tesfa et al. (2013)[21]Biodiesel is one of the alternative fuels which is renewable and environmentally friendly and can be used in diesel engines with little or no modifications. In the present study, experimental investigations were carried out on the effects of biodiesel types, biodiesel fraction and physical properties on the combustion and performance characteristics of a (compression ignition) CI engine.

R. Prakashet al. (2014)[22]Preliminary investigations on characterisation and utilisation of emulsions obtained from Wood pyrolysis oil (WPO) and Jatropha methyl ester (JME) revealed that up to 15% of WPO can be emulsified with the JME and used as a fuel in a DI diesel engine. From the experimental results in terms of emulsion stability, combustion, performance and emission parameters, the emulsion prepared from 81% by volume of JME, 15% by volume of WPO with the help of a mixed surfactant 4% by volume was found to be a better emulsion for further investigation. However, it was found that the emulsion was acidic in nature, due to the addition of WPO.

R. Senthilet al.(2014)[23]The brake thermal efficiency of various biodiesel blends and diesel is perceived. It is observed that BTE of engine and its blends are slightly lower than that of diesel fuel.

Pankaj dubey et al.(2016)[24]The significance of this present investigation undertakes the feasibility study of a new combination of bio-fuels. For this rationale; the diesel engine operated with blends of Jatropha biodiesel and turpentine oil with a view to completely eliminate dependency on fossil fuel. Jatropha biodiesel (methyl ester) and turpentine oil is a high and low viscosity fuels combination with comparable heating values to that of diesel; this makes conducive for its use in a diesel engine. Extensive experimental work is carried out on a Kirloskar make the single cylinder, natural aspired diesel engine to examine combustion performance and emission characteristics using Jatropha methyl ester with turpentine oil blends (dual fuel blends) and conventional diesel. Dual fuel blends are found to be the best substitute to conventional diesel fuel in all aspects such as performance and emissions. Further, BT 50 resulted at full load condition, reduction of 2.9%, 4.72%, 4.56%, 42.5% and 29.16% in the brake thermal efficiency,

(a) Research Gap - This comprehensive study on biodiesel; its sources, production, emission, engine performance characteristics and technological issues reported in literature were analysed to formulate the research work pattern and for better understanding of the work undertaken looking in to following parameters:
   (i) Production and sources of biodiesel
   (ii) Performance parameters with biodiesel
   (iii) Emissions with biodiesel

A lot of work has been done on the study of performance and emission characteristics of alternate fuels in IC engines. Limited amount of work has been done related with using of dual blended fuel and testing of engine parameters and engine emission at different load condition. To obtain optimal performance condition of tribological parameters for different blend ratio.

III METHODOLOGY

Engine performance characteristics can be determined either experimentally or analytically based on the experimental data. The term "performance" usually means how well an engine is doing its required task in relation to the input energy or how effectively it provides useful energy in relation to some other comparable engines. It has been tried to investigate the optimum operating temperature of engine that will deliver the best performance level. The blends of biodiesel (jatropha and karanja) in varying proportions were prepared and investigated in single cylinder, four stroke CI engine computerized test rig.

(a) Biodiesel Preparation Method - Here starting from the raw material used for biodiesel production along with its method each step for biodiesel production is explained. Various properties of the prepared biodiesel are discussed later.

- The following resources are required
- Thermometer
- Magnetic plate stirrer
- 50ml flask
- Weighing scale (accurate to 0.01 grams)
- Funnel
- Methanol 99% purity
- Potassium Hydroxide (KOH) 85 % purity
- Sodium Hydroxide (NaOH)
- Separating flask
- Jatropha oil
- Karanja oil

(i) Procedure

Step one: Purification - Jatropha oil and karanja oil was heated to about600C for about thirty minutes while stirring to reduce water content in the oil. The oil was then passed through a sieve while still hot to filter off solid particlesand debris.

- **Step two: Pre-treatment process** - Both jatropha and karanja oil reacts with methanol in the presence of the catalyst (H_2SO_4) to produce glycerol and fatty acid ester. Specified amount 500 ml of Jatropha oil 100 ml methanol and 4 ml catalyst (H_2SO_4) by volume ratio were taken in a round bottom flask. The mixture was heated to 500C and stirred (2 h) till ester formation began and then cool about 18 h at a separating flask without stirring. In the separating flask, two layers were formed. The top layer was the ester and bottom layer consisted of glycerol. Same process also followed for karanja oil.
- **Step three: transesterification** - In third post treatment process pre-treated Jatropha oil react with methanol in the presence of

the catalyst (NaOH/KOH) to produce glycerol and fatty acid ester. Specified amount 500 ml of pre-treated Jatrophaoil 100 ml methanol and 4 g catalyst (NaOH) by a volume weight ratio were taken in a round bottom flask and apply thesame above process till two layers were formed. The top layer was the ester and bottom layer consisted of glycerol.

- **Step four: Separation** -Since glycerol has a higher density than biodiesel, it settled at the bottom of the container. After 24-hours of separation, the tap beneath the container was opened and glycerol was drained off.
- **Step five: Washing and Drying** - Crude biodiesel was washed three times by agitation with clean water to remove traces of methanol and KOH from the oil. After each wash, the oil was transferred to the settling container for about four hour where it was allowed to separate. The amount of water used in each wash was equal to the amount of oil being cleaned. Water was then drained off after separation. It was noted that using warm water hastened the separation processes.

Finally the oil (biodiesel) was heated to about 110°C for about thirty minutes while stirring to evaporate off residual water from the washing process.

(b) Preparation of Engine Performance Test Samples - First be sure that biodiesel blending components all meet BS15607:2005 specification. Biodiesel blending procedures depend on a variety of factors, including the volume of B100 required to make the blend, the finished blend level, the volume of blended products being sold, tank and space availability, and equipment and operational costs. The temperature of the biodiesel should be a minimum of 60°F or 10°F above the cloud point when being blended.[12]

IV EXPERIMENTAL WORK

A computerized CI engine test rig was used for this experimental investigation. This experimental test rig consists of a single cylinder, four strokes, constant speed, water cooled, direct injection diesel engine, having a rated power output of 5.22 kW at a constant speed of 1500 rpm. The test rig have eddy current dynamometer as loading system, water cooling system, lubrication system and various sensors and instrumentation integrated with computerized data acquisition system for online measurement of load, air & fuel flow rate, instantaneous cylinder pressure, position of crank angle, exhaust emissions and smoke

Fig. No. 4.1 Photograph of experimental set up in IC Engine Laboratory

The experiments are carried out on a single cylinder, direct injection, Kirloskar TV1, water cooled, naturally aspirated engine. It was chosen for the existing investigation. This engine is mostly used for domestic electricity generations and agricultural activities. A layout of the experimental setup along with all instruments is shown in fig 4.1TheKistler makes pressure sensor and TDC sensor was fitted at the cylinder head near the flywheel to measure the pressure of the combustion chamber and the crank angle at different engine loadings. The fuel injection system was the conventional, cam-driven, in-line (Pump-Line-Nozzle) fuel injection system which injects the fuel at 200–220 bars. Technical specifications of the engine are given in table .A fuel tank of 5 L capacity was mounted at the back of the panel on the wall with manual fuel consumption measuring burette which is nearer to the engine at the highest position. AVL CDS 250 exhaust gas analyzer attached to the computer was used for the measurements of various exhaust gas parameters like CO, HC, CO2 and NOx. The accuracy and reproducibility of the instrument were 1% of full-scale reading. AVL 437 smoke meter attached to the exhaust manifold to measure the smoke emission, which work on light extinction principle. A personal computer connected the software 'DAQ factory software' was provided by Legion Brothers. The Legion data acquisition system has been used to record major parameters such as ignition delay, combustion duration, mass fraction burns angle, engine speed (rpm), in-cylinder gas pressure, crank angle measurement, heat release rate and the indicated power. To apply different engine loads an eddy current dynamometer (manual) maximum rated power 7.5 kW at 1500– 3000 rpm controlled by a switch providing in control panel coupled to the engine. At the steady state condition, the data collected and stored in the computer for post processing. The test was repeated to take the peak value so as to minimize the effect of fluctuations. The fresh lubricating oil 20W40 is filled in oil sump before starting the experiments. The engine is provided with necessary instruments for combustion pressure and crank-angle measurements.

(a) Table No. 4.1
Specification of the engine

model	TV1, Kirloskar oil Engine Ltd. India
type	Single cylinder, four stroke, water cooled, constant speed, direct injection, compression ignition engine
bore	87.5mm
stroke	110mm
Max power	5.22KW
speed	1500rpm
Compression ratio	17.5:1
Injection pressure	210- 220 bar
governer	Mechanical(centrifugal) type
Dynamometer	Eddy current
Pressure sensor	Kistler
Crank angle measurement	Magnetic TDC pick up sensor
TDC at	360^0 crank angle
Start of injection at	23 deg before TDC
Sensor response	Piezo electric
Resolution crank	1 deg crank angle

(i) **Required**

- **Engine exhaust:** Engine exhaust connection is taken out of the lab by shortest straight route and bends are voids.
- **Electric supply:** The setups need single phase electric supply with proper ear thing. The typical supply voltages should be Phase–Neutral: 220V-240 V; Phase-Earth: 220V-240V; Neutral-Earth: 0- 5V Max. This should not exceed 5V.
- **Computer:** Provide computer of standard configuration with DVD drive (for computerized engine test setup). The computer has 3GB RAM and USB port for communication. The computer may need to be formatted before installing 'DAQ factory software.
- **Water supply:** Continuous, clean and soft water supply @ 2000 LPH, at 10 m. head. Provided tap with 1"BSP size connection. Water recirculation is avoided as the inlet water will continuously heat up and steady state shall not be achieved. Engine set up is supplied with water pump.
- **Software:** DAQ factory software was provided by Legion brothers. The Legion data acquisition system has been used to record major parameters such as ignition delay, combustion duration, mass fraction burns angle, engine speed (rpm), in-cylinder gas pressure, crank angle measurement, heat release rate and the indicated power.

(b) **Measurement Systems -** Various measurement systems used to capture the experimental data used in the test rig are load measurement system, fuel injection pressure measurement system, cylinder pressure measurement system, emission measurement system and data acquisition system.

(i) **Load measurement system:** The experimental study is conducted at various loads and hence an accurate and reliable load measuring system is a must. The load measuring system of this experimental test rig consists of a dynamometer of eddy current type, a load cell of strain gauge type and a loading unit. The load is applied by supplying current to the dynamometer using a loading unit. The load applied to the engine is measured by a load cell. The dynamometer, load cell and loading unit.

(ii) **Load cell:** A load cell is a transducer that is used to convert a mechanical signal (force) into an analogous electrical signal.

(iii) **Loading unit:** The loading unit consists of a dimmer stat to control the magnitude of the direct current flowing into the dynamometer and a switch to ON/OFF the loading unit. The current is supplied into the loading unit through the main power supply.

(iv) **Cylinder Pressure Measurement System:** The cylinder pressure is measured using a Piezo sensor of Make kistler group Thepiezo sensor consists of a quartz crystal. One end of the sensor is exposed to the cylinder pressure through the diaphragm. As the pressure inside the cylinder increases the crystal is compressed. Since the piezoelectric crystals have a tendency to generate electric charge when deformed, the sensor generates electric charge proportional to the pressure.

(v) **Commercial Software - DAQ factory software:** 'DAQ factory software' was provided by Legion Brothers. The Legion data acquisition system has been used to record major parameters such as ignition delay, combustion duration, mass fraction burns angle, engine speed (rpm), in-cylinder gas pressure, crank angle measurement, heat release rate and the indicated power.

(vi) **Emission Measurement System** - The emission measurement system is used to measure the constituents of exhaust gas and its opacity (smoke number). This system consists of an exhaust gas analyzer and a smoke meter. The exhaust gas analyzer measures the exhaust gas constituents of Carbon dioxide (CO2), Carbon monoxide (CO), Oxides of nitrogen (NOx), Unburnt Hydrocarbons (HC) and Oxygen (O2). The smoke meter is used to measure the intensity of exhaust smoke and it is measured.

(vii) **Exhaust Gas Analyzer:** An instrument used to analyze the chemical composition of the exhaust gas released by a reciprocating engine is called exhaust gas analyzer. The instrument measures the concentrations of Carbon monoxide (CO in % & ppm), Carbon Dioxide (CO2) and Oxygen (O2) in percentage, Hydrocarbons (HC) and Nitric Oxide (NOx) in ppm in the engine exhaust gas.

V CONCLUSION

The present work has tried to use dual fuel, Jatropha biodiesel and karanjaoil in a compression ignition diesel engine, eliminate the use of standard diesel completely and without any modification. Under this, the properties of both fuels are acceptable and favorable for use in the diesel engine. The dual fuel blends were investigated and compared to pure diesel on combustion, performance and emission characteristics of the engine. The salient points are as follows.

(a) In the use of dual fuel blends, the engine operated successfully & smoothly and performed better; the BTE is lower as compared to being conventional diesel fuel.

(b) Regardless of the load conditions dual fuel blend, BT50 gives lower NOx, CO, HC emission as compared to mineral diesel fuel. Moreover, at full load condition,

(c) Jatropha methyl ester has lower volatility and higher viscosity compared to karanja oil, which might have karanjaoil caused proper mixing and complete combustion; therefore, dual fuel blends shows lower emissions.

(d) It has found that the significant physical and chemical properties of bio fuel for CI engine use are mostly within the corresponding values for pure diesel fuel. The main exception is viscosity, calorific value and oxygen content.

(e) Although literature on short run test suggest that bio fuels can replace convention diesel fuel along run analysis is essential for assessment of engine life.

(f) Regarding the performance and emissions of engines running on bio fuels, a review of sources has shown that, compared to Chemical modification of vegetable oil improves the quality of oil that makes the applicability in a wide area. Continue research in these areas promises to lead to a more detailed understanding of tribological characteristic of various non-edible vegetable oils.

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