PERFORMANCE, EMISSIONS AND COMBUSTION EVALUATION OF CI ENGINE USING BIOFUEL

Ravindra A Patil, Prof. Tushar A Koli, Prof. V.H.Patil

Abstract— **Recent studies reveal that increasing fuel prices and scarcity of its supply have promoted interest in development of alternative sources for petroleum fuels. Vegetable oil is receiving increasing attention each passing day because of fuel properties and compatibility with petroleum based diesel fuel. Therefore in this paper the prospects and opportunities of using Palm Straight Vegetable oil as a fuel in an engine are studied. In the present research work tests were conducted on a four strokes, Single cylinder, and D.I diesel engine with essential instruments to carry out the performance and emission tests on Diesel and various blends of palm Straight Vegetable oil. The results of performance and emission tests are compared with various blends of palm Straight Vegetable oil with that of neat diesel, from the tests it is observed that as the blend percentage is increasing the fuel parameter and the emissions quality is decreasing due to increase in viscosity. So from the results it can be concluded that 10% blend is considered as the best compare to other blends at 95% load condition.**

Index Terms— **Straight Vegetable Oil (SVO), Palm oil, Diesel Engine, Performance Parameters.**

I. INTRODUCTION

The use of vegetable oils as an alternative fuel for diesel engine dates back to around a century. Vegetable oils have some advantages. They are renewable, easily available in the rural areas, have high cetane number, heat release is similar to diesel, its emission rate is similar to diesel, it's emission rate is relatively low to be used in Compression Ignition engines with simple modifications and can be easily blended with diesel. Jatropha oil, sesame oil, coconut oil, sunflower oil, neem oil, mahua oil, peanut oil, palm oil, rubber seed oil, cotton seed oil and rape seed oil are some of the vegetable oils that have been tried as fuel in Internal combustion engines. Rudolph Diesel the inventor of the Diesel engine experimented with fuels ranging from powdered coal to peanut oil. In the early 20th century and ultimately successes to burn petroleum distillate in diesel engines because it was cheap and plentiful of fuel at that time. In the late 20th century, the cost of petroleum increased in faster rate i.e. in the period of 15 years cost increased 15 times more to the previous cost and at the same rate fuel reserves are depleting, and by the late 1970s there was renewed interest in biofuel. Due to rapid decline of crude oil reserve and increase in price, the use of vegetable oils is again prompted in many countries. Depending upon soil condition and climate, different nations are looking for different vegetable oils for example, soybean Mustard Oil in Bangladesh, rapeseed and sunflower oil in Europe, palm oil in Malaysia and Indonesia, coconut oils in Philippines are being considered to substitute of diesel fuel.

II. LITERATURE REVIEW

[1]Koli et al showed that the performance parameters of dual vegetable oil blends (mixture of Mustard oil and Palm oil) with diesel on a stationary single cylinder, four stroke direct injection compression ignition engine. The blends of BB 10 (combination of Diesel 90% by volume, Mustard oil 5% by volume and Palm oil 5% by volume) and blends of BB 20 (combination of Diesel 80% by volume, Mustard oil 10% by volume and Palm oil 10% by volume) gave better brake thermal efficiency, lower total fuel consumption and lower brake specific fuel consumption than other blends (BB 30, BB 40 and BB 50).

Reddy et al. [2] Showed that retarding the injection timing with enhanced injection rate of a single cylinder, constant speed, and direct injection diesel engine operating on neat Jatropha SVO improved the it's performance and emission level significantly. The measured emissions were even lower than petrodiesel. At full load, HC emission level was observed to be 532 ppm against 798 ppm for petrodiesel, NOx level was 1163 ppm against 1760 ppm and smoke was reduced to 2.0 BSU against 2.7 BSU. However, the BTE with

Ravindra A Patil, Mechanical Department, GF'S GCOE North Maharashtra University Jalgaon., Jalgaon, India, 09730951618
Tushar A Koli, Mechanical Department, GF'S GCOE North Maharashtra University Jalgaon., Jalgaon, India, 09423185087,
V H Patil, Mechanical Department, GF'S GCOE North Maharashtra University Jalgaon, India, 09373950013.

ISSN: 2278 – 7798

Jatropha SVO (28.9%) was lower than with petrodiesel (32.1%).

S.Bajpai et al. [3] conducted tests of karanja SVO blended with petrodiesel on a single-cylinder constant speed (1500 rpm) diesel engine having compression ratio 17.5. The results are very promising especially in the case of Indian scenario. They concluded that petrodiesel blended with 10% neat karanja SVO (termed as KVO10) can be adopted as an alternative fuel for existing conventional CI engines without any major hardware modifications, as this blend showed improved BTE and reduced BSEC and exhaust emissions. They reported that decrease in EGT of a karanja SVO fueled engine led to an approximately 4% decrease in NOx emissions for KVO10. They also conducted fuel characterization of preheated karanja SVO. They reported that with preheating the viscosity of karanja SVO at 900C was found to be very close to that of petrodiesel. Finally, they concluded that the self-lubricity and oxygen content of karanja SVO played a key role in engine performance. Fuel preheating and exhaust gas recirculation is recommended for the CI engine to be operated with optimum test fuels.

Devan et al. [4] conducted tests using neat poon oil (Sterculia foetida) and its blends with petroleum diesel on a single-cylinder 4-stroke air-cooled CI engine developing 4.4 kW at 1500 rpm. They concluded that the engine power output and fuel consumption of the engine are almost the same when the engine is fueled with lower poon oil-petrodiesel blends compared with those of petrodiesel. They observed, at full load, a 32% reduction in NOx emission for poon SVO and 4% reduction for its 20% blend. The CO emissions from neat poon oil and its blends were higher except in the case of the neat 20 blend where it reduced by 12%. They observed an increase in HC emission by 18% with neat poon oil, whereas 14% reductions with neat 20 blend. They, finally, concluded that lower poon oil-petrodiesel blends are potentially good substitute fuels for diesel engines.

Ziesjewski et al. [5] in their experiment blended 25% sunflower SVO and 75% petrodiesel and used it as a fuel in CI engine. They concluded that dilution of SVOs with solvents lowers the viscosity. By this way some engine performance problems such as injector coking and more carbon deposits could be addressed.

Sahoo and Das [6], based on their work with Jatropha, karanja, and polanga biodiesels, have concluded that the appropriate blend necessary to ensure optimum performance, low-emission and best combustion characteristics depends upon the particular feedstock and the subsequent biodiesel formulation and unrefined Jatropha, karanja, and polanga seed oil is quite suitable as an alternative to diesel. They observed that the ignition delays are shorter than petrodiesel and the difference is increasing with the load. These are varying between 5.90 and 4.20 CA for 100% jatropa biodiesel, between 6.30 and 4.50 CA for 100% karanja biodiesel, and between 5.70 and 4.20 CA for100% polanga biodiesel. Further, the 100% polanga biodiesel resulted in highest peak cylinder pressure.

Montague [7] conducted experiments by using rapeseed biodiesel in automotive diesel engines. The introduction of 5% of RME led to a reduction in the volumetric efficiency around 0.4%.It has been reported that, even after a 71, 50,000 km run by vehicles no abnormal aging was observed. The increase in NOx and decrease in HC were detected. The increase of noise and smoke level occurrence during cold start was also noted.

It may be inferred from the various research works that SVO blends are a possible biofuel source for CI engine. However, these oils are low volatility and extremely viscous, with viscosities ranging from 10 to 17 times greater than diesel fuel with 10 to 20 carbon number hydrocarbons [8–10]. Different methods have been considered to reduce the viscosity of vegetable oils such as heating, dilution, micro emulsification, pyrolysis, catalytic cracking and transesterification. As the oil temperature increases its viscosity decreases [11]. The lower the viscosity of the biodiesel, the easier it is to pump and atomize and achieve finer droplets [12]Further, the problems met in long-term engine tests, may be coking on injectors, valve seats more carbon deposits, oil ring sticking, and thickening and gelling of the engine lubricant oil [13–14].

III. OBJECTIVE

The aim of the present study is to evaluate the performance using different blends of palm oil with diesel in a CI engine.

To investigate the feasibility of Palm oil as a biofuel source for CI engines and identify the most suitable blends through engine performance, Emission, and combustion analysis.

The following are the major objective to fulfill the aim of present study

1. Collection of palm oil from local market.
2. Determination of physical properties of Palm oil.
3. Study the effect of blending of Palm oil with diesel.
4. Performance evaluation of diesel engine using different blends of palm oil with Diesel.

ISSN: 2278 – 7798

IV EXPERIMENTAL SETUP

A. Engine

The engine is single cylinder Four Stroke Diesel engine having maximum power output 7hp (approx.) at 2000 rpm. It is a constant speed engine.

B. **Eddy Current Dynamometer**

Eddy Current Dynamometer coupled to engine through propeller shaft. The Dynamometer consists of a rotor inside a winding of electrical conductor coil. As current is passed through the coil, it creates braking action on the rotor thus increasing the torque. By varying the current supplied to the coil, torque can be changed.

C. Exhaust Gas Calorimeter

It is basically a counter flow type shell and tube type heat exchanger having a set of number of forge copper tubes in center. Flue gas is passing through this tube and water is flowing over the tubes inside shell. Heat is transferred from exhaust gas to the water. By knowing the temperatures of gas and water at entry and exit, heat carried away by exhaust gas can be calculated.

D. Control Panel: following components are mounted on this panel

Torque Controller cum indicator:

The loading of dynamometer is controlled by digital torque indicator cum controller.

Engine Speed Indicator:

The Engine speed is measured by magnetic pickup. The output of sensor is given to the RPM indicator mounted on panel.

Manometer:

U tube manometer is provided to measure the pressure difference between ambient air and air inside the box.

Temperature measurement:

For heat balance analysis sensors are connected at exhaust gas calorimeter and engine cooling.

E. Air flow measurement:

Air flow is measured using an air box Orifice is fixed in the inlet of air box suction pressure difference across the orifice is read on the U-tube manometer mounted on the panel. The outlet of the air suction box goes to the engine through the flexible hose for air suction.

F. Fuel measurement:

This is done by using burette which is mounted on the control panel. The fuel tank is mounted on panel. The fuel is supplied to engine using a fuel line to fuel injection system. The amount of fuel consumed is determined by the change in the readings shown on the burette. A three –way cock is used both to fill the burette and to allow the fuel to flow to the engine.

Fig. Setup of the engine

Make	Kirloskar Oil Engines
Model	TV1
Type	Four stroke
Cooling type	Water cooling
No. of cylinder	One
Bore	87.5 mm
Stroke	110 mm
Combustion principle	Compression ignition
Cubic capacity	0.661 liters
Compression ratio	17.5:1
Max. speed	2000 rpm
Min. idle speed	750 rpm
Min. operating speed	1200 rpm
Continuous Power rating	7/1500 hp/rpm
Lubricating oil pump	Gear type
Overall dimensions	617 L x 504 W x 877 H

Table1. Specification of the test engine.

Physio chemical properties of palm oil and its blends with petrodiesel

Property	PO10	PO15	PO20	PO30	PO40	PO100	Diesel
Density, kg/m^3	848	854	859	867	878	901	835
Calorific Value, MJ/kg	43.62	43.53	43.46	42.94	42.05	39.81	44.62
Kinematic Viscosity @ 40^0 C	4.32	4.60	5.35	6.52	8.22	40.42	2.83
Flash Point, ^{0}C	102	112	123	136	162	262	72
Cloud Point, ^{0}C	8.1	9.3	10.3	11.2	12.4	16	6.4
Pour Point, ^{0}C	4.2	4.4	4.5	5.1	5.7	6.0	3.0
Cetane Index						46	48

V. EXPERIMENTAL PROCEDURE

1. Fill the fuel tank with the fuel.
2. Start the cooling water supply to the engine and the
3. Calorimeter.
4. Fill the burette with fuel.
5. Start the engine with cranking handle provided.
6. Note down the readings in observation table.
7. Load the engine gradually by applying torque.

ISSN: 2278 – 7798

8. Note down the readings for various loads.

VI. CALCULATIONS

The basic performance parameter that was determined for performance evaluation of engine is:

1. Brake power (BP)
2. Brake thermal efficiency (BTE)
3. Break Specific Energy Consumption (BSEC)
4. Exhaust Gas Temperature (EGT)
5. CO Emission
6. NOx Emissions
7. Unburnt Hydrocarbon Emissions (UBHC).

Various formulae that were used for performance evaluation are listed below:

Brake Power (BP): The brake power is the power developed by the engine at the Output shaft and is given by;

$$BP = \frac{2\pi NT}{1000}$$

Brake thermal efficiency (η_{bth}): A measure of overall efficiency of the engine is given by the brake thermal efficiency. Brake thermal efficiency is defined as the ratio of energy in the brake power to the fuel energy.

$$\eta_{bth}(\%) = \frac{\text{BrakePower(KW)} \times 3600}{\text{Fuel Flow}\left(\frac{kg}{hr}\right) \times \text{Calorific Value(kJ/kg)}} \times 100$$

Total Fuel Consumption (TFC):

$$TFC = \frac{\text{cc (ml)}}{\text{time}} \times \frac{\text{specific gravity}}{1000}\ \text{kg/sec}$$

Brake Specific Fuel Consumption (BSFC): Brake specific fuel consumption is the amount fuel consumed per kW of brake power developed and is given by,

$$BSFC = \frac{mf}{bp}$$

Brake Specific Energy Consumption (BSEC): Brake specific fuel consumption is the amount fuel consumed per kW of brake power developed and is given by,

$$BSEC = \frac{Energy\ Supplied\ by\ the\ fuel}{BP}$$

VII. EMISSION ANALYSIS

These various gas emissions like carbon dioxide, carbon monoxide, oxygen, Hydrocarbons, and the oxides of nitrogen are measured with the help of Gas analyzer (AVL DIGAS 444).

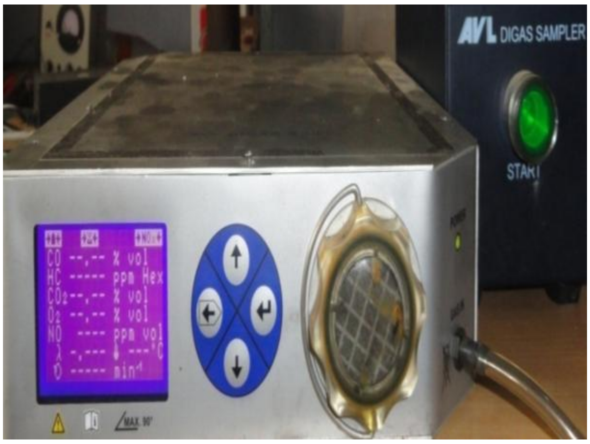


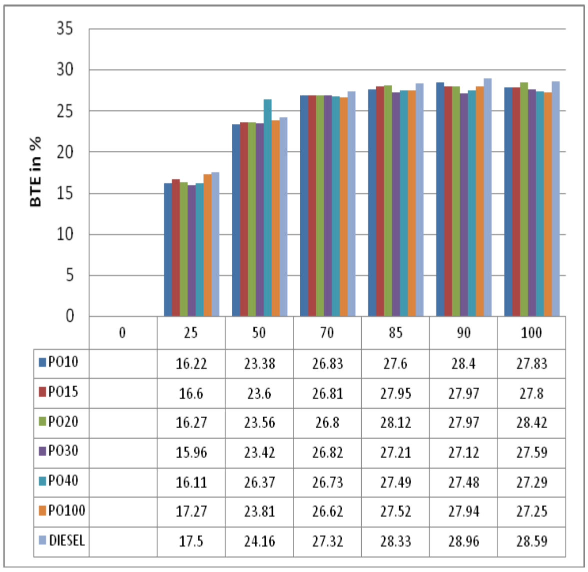
Fig. Gas Analyser

The measuring range of the gas analyzer is given below in Table:

Measuring Quantity	Measuring range
CO	0- 10%
CO_2	0-20%
HC	0-20000 ppm
O_2	0-22%
NO_X	0-5000 ppm

VII. RESULTS

1. BTE vs LOAD for All Blends of Palm Oil and Diesel

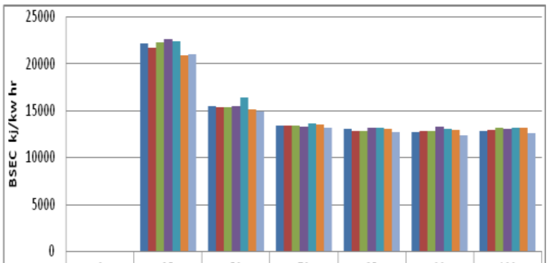


	0	25	50	70	85	90	100
PO10		16.22	23.38	26.83	27.6	28.4	27.83
PO15		16.6	23.6	26.81	27.95	27.97	27.8
PO20		16.27	23.56	26.8	28.12	27.97	28.42
PO30		15.96	23.42	26.82	27.21	27.12	27.59
PO40		16.11	26.37	26.73	27.49	27.48	27.29
PO100		17.27	23.81	26.62	27.52	27.94	27.25
DIESEL		17.5	24.16	27.32	28.33	28.96	28.59

- There was considerable increase in efficiencies with the PO and its blends with increase in load.
- Poor combustion due to high viscosity and poor volatility of PO the combustion is poor due to that BTE decreases with increase in PO percentage.
- From the above results it has been seen that Palm oil 10% blend at 90% load condition is considered as best as compared to other blends.

2. BSEC vs. LOAD for All the blends of Palm Oil and Diesel

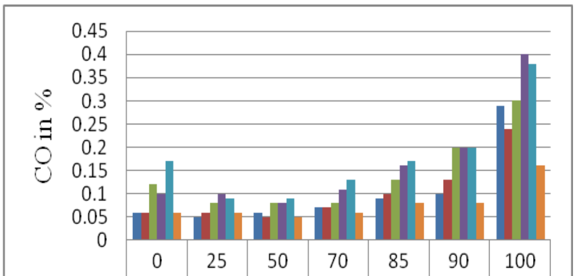
ISSN: 2278 – 7798



	0	25	50	70	85	90	100
PO10		22138.02	15430.2	13374	13084	12723	12900
PO15		21640	15312	13377	12841	12896	12958
PO20		22262	15313	13384	12794	12860	13170
PO30		22564	15435	13294	13237	13258	13052
PO40		22345	16428	13686	13151	13080	13222
PO100		20825	15142	13570	13120	12935	13216
Diesel		21029.19	14942.08	13230.76	12700	12394.67	12570.56

- With increase in PO content in the mixture the BSEC is increasing.
- The brake specific energy consumption of PO blends is higher than diesel for all loads.
- Differences in BSEC are largely due to the lower heating value of the PO resulting in required mass fuel flow increase needed to obtain equal fuel energy input.
- So in respect of other blends 10% blend at 90% load condition is considered as best.

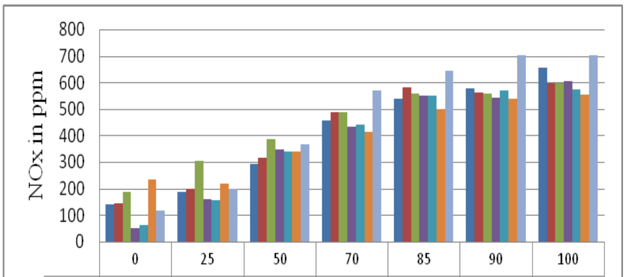
3. CO emissions vs LOAD for All Blends of Palm Oil and Diesel



	0	25	50	70	85	90	100
PO10	0.06	0.05	0.06	0.07	0.09	0.1	0.29
PO15	0.06	0.06	0.05	0.07	0.1	0.13	0.24
PO30	0.12	0.08	0.08	0.08	0.13	0.2	0.3
PO40	0.1	0.1	0.08	0.11	0.16	0.2	0.4
PO100	0.17	0.09	0.09	0.13	0.17	0.2	0.38
Diesel	0.06	0.06	0.05	0.06	0.08	0.08	0.16

- It increases with increase in Palm oil blend and is lowest for diesel.
- This is because of high viscosity and low volatility and slower evaporation Palm Oil does not burn completely resulting in poor combustion.
- Due to the poor combustion the carbons are changed into CO.
- It has been seen that at 90% load condition 10% blend is best compared to other blends.

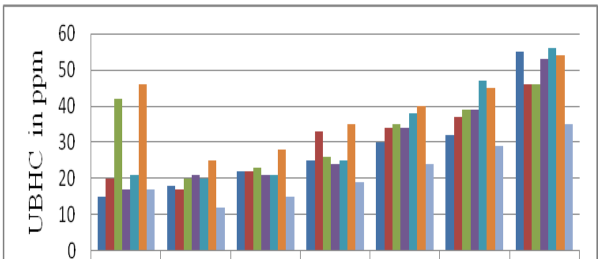
4. NOx Emissions vs. LOAD for All Palm Oil Blends and Diesel



	0	25	50	70	85	90	100
PO10	140	186	291	455	538	579	655
PO15	144	200	318	489	583	562	599
PO20	187	306	385	487	558	557	596
PO30	51	159	346	432	549	541	604
PO40	64	158	338	441	550	569	575
PO100	234	218	340	412	499	537	553
Diesel	119	199	367	569	642	701	703

- NO_x is a direct function of engine loading because with increase in load, combustion chamber temperature increases.
- NO_x emission decreases with increase in Palm Oil in blend which may be lower average temperature and decrease in fuel evaporation in case straight vegetable oils.
- Complete combustion occurs for diesel for which the NOx emission is higher.
- For the 10 % blend is considered as best in respect of NOx emission compare to other blends and in that blend it works best at 90% load condition.

5. Unburnt Hydrocarbon Emissions (UBHC) vs. LOAD for All Palm Oil Blends and Diesel



	0	25	50	70	85	90	100
PO10	15	18	22	25	30	32	55
PO15	20	17	22	33	34	37	46
PO20	42	20	23	26	35	39	46
PO30	17	21	21	24	34	39	53
PO40	21	20	21	25	38	47	56
PO100	46	25	28	35	40	45	54
Diesel	17	12	15	19	24	29	35

- Unburned hydrocarbon increases with increase in PO in blend and is lowest for diesel.
- Effect of fuel viscosity on fuel spray quality would be expected to produce some HC increase with SVO.
- Because higher viscosity leads to higher spray droplet size which results in incomplete combustion resulting in higher HC formation compared to diesel.

ISSN: 2278 – 7798

- Only 10% blend is comparable to the diesel at 90% load condition.

VIII.CONCLUSIONS

- The Engine performed best at the 90% loading condition for Palm straight vegetable oil. The results are comparatively similar for diesel fuel and this is also comparatively similar with the available literature. So the engine may be operated at 90% loading condition for Palm straight vegetable oil.
- With the increasing of the percentage of Palm straight vegetable oil in the blends the NOx emissions are showing decreasing trend. This decreasing trend resembles the improper combustion and reduction in cylinder temperature due to the increase of the viscosity of the fuel.
- From the comparison for all blends 10% Palm straight vegetable blend is considered as best and which is matching with the available literature.
- So the engine performed best for the 10% Palm oil blend at 90% load condition.

IX. FUTURE SCOPE OF PRESENT WORK

The present work may extend further in the following directions:

- Using different additives in Palm straight vegetable oil to find out their suitability in the similar applications.
- Using parent straight vegetable oils as additives in the biodiesel fuel to find out the suitability in the similar applications.
- Application of exergy analysis considering the chemical composition of the fuel mixtures.

X. REFERENCES

[1] C S Koli, Ram Bansal, Amit Agrawal, Ashish Agrawal 2014, " Experimental Investigation of performance of single cylinder 4s Diesel engine Using Dual Vegetable Oil Blended", Journal of Engineering Research and Applications, march 2014, pp78-85

[2] Reddy J.N.and Ramesh A.2006, "Parametric Studies for Improving the Performance of a Jatropha Oil-fueled Compression Ignition Engine", Renewable Energy, Vol.31, pp. 1994–2016.

[3] Bajpai S., Sahoo P.K., Das L.M., 2009, "Feasibility of Blending Karanja Vegetable Oil in Petro-diesel and Utilization in a Direct Injection Diesel Engine", Fuel, Vol. 88, pp. 705–11.

[4] Devan P.K.and Mahalakshmi N.V., 2009, "Performance, Emission and Combustion Char-Acteristics of Poon Oil and its Diesel Blends in a DI Diesel Engine", Fuel, Vol. 88, pp. 861–7.

[5] Ziejewski M., Goettler H., and Pratt G.L., 1986, Paper No. 860301, International congress and exposition, Detroit, MI; February, pp. 24–8.

[6]Sahoo P.K and Das L.M., 2009, "Combustion Analysis of Jatropha, Karanja and Polanga based Biodiesel as Fuel in a Diesel Engine", Fuel, Vol. 88, pp. 994–99.

[7]Montague X., 1996, "Introduction of Rapeseed Methyl Ester in Diesel Fuel-the French National Program", SAE 962065.

[8]Kuar M.S. Ramesh A. and Nagalingam B., 2003, "An Experimental Comparison of Methods to use Methanol and Jatropha Oil in a Compression Ignition Engine", Biomass and Bioenergy, Vol. 25, pp. 309–18.

[9] Rao P.S. and Goapalkrishnan K.V., 1991, "Vegetable Oils and their Methyl Esters As Fuel in Diesel Engines, Indian Journal of Technology, Vol. 29, pp. 292–7.

[10] Reddy J.N.and Ramesh A., 2006, "Parametric Studies for Improving the Performance of a Jatropha Oil-fuelled Compression Ignition Engine", Renewable Energy, Vol. 31, pp. 1994–2016.

[11]Karaosmonoglu F., 1999, "Vegetable Oil Fuels: A Review", Energy Source, Vol. 21, pp. 221– 31.

[12]De Almeida Silvio C.A., Rodrigues Belchior C., Nascimento Marcos V.G. Vieira Leonardo dos S.R., and Fleury G., 2002, "Performance of a Diesel Generator Fuelled with Palm Oil", Fuel, Vol. 81, pp. 2097–102.

[13]Kenneth J.S., "Vegetable Oil or Diesel Fuel–A Flexible Option", SAE paper No. 840004.

[14] Barsic N.J. and Humke A.L., "Performance and Emissions Characteristics of a Naturally Aspirated Diesel Engine with Vegetable Oil Fuels",SAE paper No. 81026.

ISSN: 2278 – 7798