Experimental Study on Performance and Emission Characteristics of Diesel Engine Using Karanja oil/Diesel as Fuel

Prof. Vimal V Prajapati[1], Dr. Ratnesh Shukla[2] and Dr. Radhashyam Giri[3]

1. *Associate Professor, Mechanical Engineering, Government Engineering College, Near Animal Vaccine, Centre Sector -28, Gandhinagar-382028, Gujarat, India*
2. *Professor, Mechanical Engineering, Government Engineering College, Bharuch, Opp. Govt. Guest House, Bholav, Bharuch-392002, Gujarat, India*
3. *Assistant Professor, Central Institute of Plastics Engineering and Technology, Plot no-630, Phase IV, GIDC, Vatva, Ahmedabad-382445*

ABSTRACT

The present paper investigates about the production of biodiesel from neat Karanja seed by chemical extraction process and mixing of the diesel in varying volume proportions in order to prepare a number of test fuels for engine application. The prepared test fuels are used in single cylinder water cooled diesel engine at various load conditions to evaluate the performance and emission parameters of the engine. The results of investigation show increase in brake power and brake thermal efficiency with load for all prepared test fuels. It is also seen from the results that HC emissions increase with increase in load for all prepared test fuels. CO emissions decrease with increase in load for all prepared test fuels. The smoke and NOx emissions also increase with increase in load for all prepared test fuels. During the course of this experimental investigation it was found that the overall performance and emission characteristics of the engine was satisfactory with all the test fuels and improved with repeated experiments. All the test results significantly improved with increase in load for all prepared test fuels. Therefore the present paper provides a strong platform to continue further investigation on using biodiesel fuel in a diesel engine.

Keywords*: Karanja oil, Biodiesel, Performance, Emission and Consumption*

---

1. INTRODUCTION

Now a day the price of petroleum oil reaches a new high, the need of developing alternate fuels has become acute. Alternate fuels should be economically attractive in order to compete with currently used fossil fuels. Biodiesel, produce by the transesterification of vegetable oils or animal fats with simple alcohols and catalyst attracts more and more attention recently. Biodiesel is clean burning diesel alternative and has many attractive features including renewability, biodegradability, non toxicity and low emission.

India is one of the fastest developing countries with a stable economic growth, which multiplies the demand for transportation in many folds. Fuel consumption is directly proportionate to this demand. India depends mainly on imported fuels due to lack of fossil fuel reserves and it has a great impact on economy. India has to look for an alternative to sustain the growth rate. Bio-diesel is a promising alternative for our Diesel needs. With vast vegetation and land availability, certainly bio-diesel is a viable source of fuel for Indian conditions. Recent studies and research have made it possible to extract bio-diesel at economical costs and quantities. The blend of Bio-diesel with fossil diesel has many benefits like reduction in emissions, increase in efficiency of engine, higher Cetane rating, lower engine wear, low fuel consumption, reduction in oil consumption etc. It can be seen that the efficiency of the engine increases by the utilization of Bio-diesel. This will have a great impact on Indian economy.

Diesel fuels have deep impact on the industrial economy of a country. These are used in heavy trucks, city transport buses, locomotives, electrical generators, farm equipments, underground mine equipments etc. The consumption of diesel fuels in India for the period 2007-08 was 28.30 million tons, which was 43.2% of the consumption of petroleum products. This requirement was met by importing crude petroleum as well as petroleum products. The

import bill on these items was 17,838 crores. With the expected growth rate for diesel consumption more than 14% per annum, shrinking crude oil reserves and limited refining capacity, India is likely to depend more on imports of crude petroleum and petroleum products.
Problems with the use of vegetable oil as fuel for internal combustion engines are as shown below:

1. Higher viscosity
2. Lower Heating Value.
3. Carbon particle deposition at tip of fuel injector.

To improve performance of engine using vegetable oil it is essential to reduce its viscosity. Transesterification is a very successful technique to reduce viscosity of vegetable oil. There are number of oils available in market which may be processed to make biodiesel.

Table 1.1 Different Edible Oil and Non Edible Oil

Sr. No	Edible Oil	Non Edible Oil
1	Palm Oil.	Neem
2	Soya Oil.	Karanja
3	Cottonseed oil.	Kusum
4	Rapeseed Oil.	Pilu
5	Mustard Oil.	Ratanjot (Jetropha)
6	Corn oil.	Jaoba
7	Sunflower Oil.	Bhikal
8	---------------	Wild Walnut
9	---------------	Undi
10	---------------	Thumba

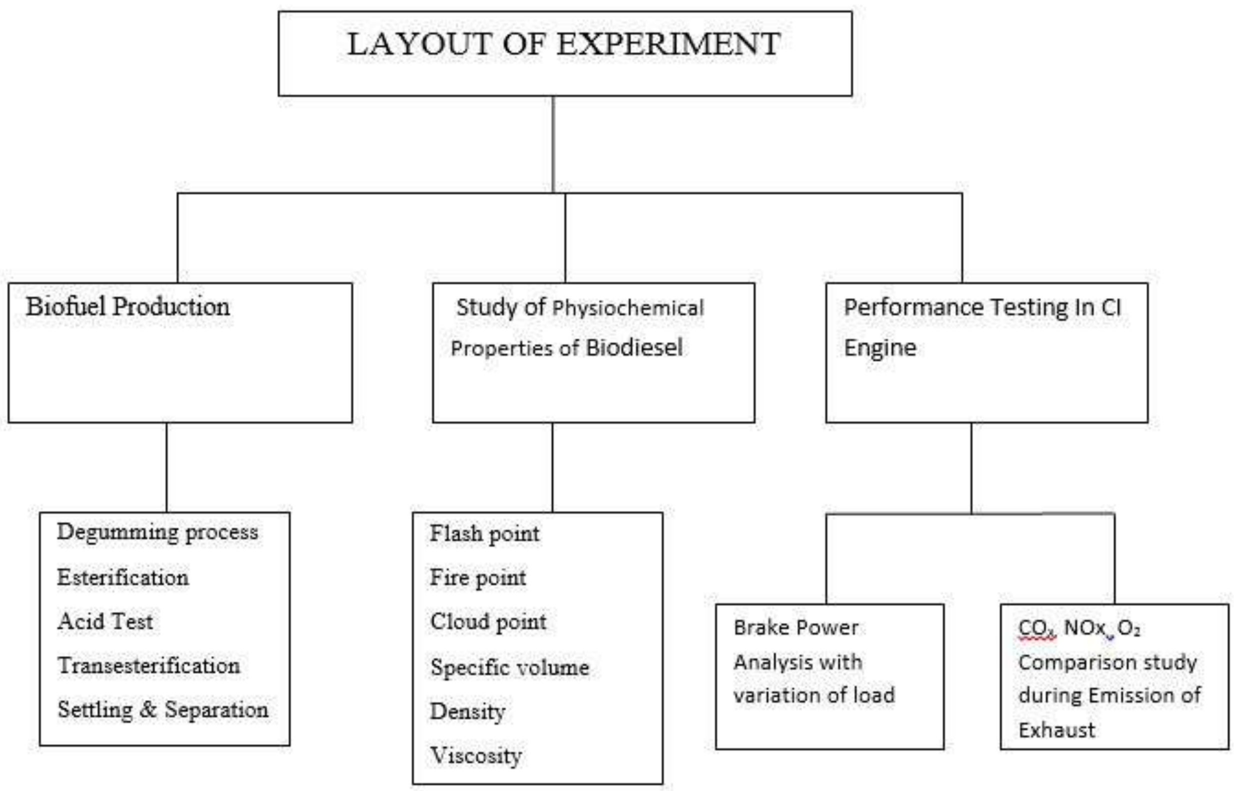
In India there is scarcity of edible oil so generally non edible oil is preferred. Considering somewhat higher cost of these oils also, efforts can be made to run engine on dual fuel mode such as diesel/biodiesel + Biogas/producer gas. In India due to considerable strength of cattle dung is available in very huge quantity. From this dung and so many options like human excreta, vegetable waste etc. biogas can be produced which is available at very cheaper rates. In India biogas is used mainly for cooking only. But efforts should be made to run diesel engine with diesel/biodiesel with biogas on dual fuel mode so that people from rural areas can fulfill their own energy requirement using locally available fuels. Few researchers done experimental work and results observed are as stated below: Jinlin Xue, Tony E. Grift , Alan C. Hansen et. al. explained in their paper on Effect of biodiesel on engine performances and emissions has reported the effect of biodiesel on engine power, economy, durability and emissions including regulated and non-regulated emissions and the corresponding effect factors are surveyed and analyzed in detail. The use of biodiesel leads to the substantial reduction in PM, HC and CO emissions accompanying with the imperceptible power loss, the increase in fuel consumption and the increase in NO_x emission on conventional diesel engines with no or fewer modification. And it favors to reduce carbon deposit and wear of the key engine parts. Therefore, the blends of biodiesel with small content in place of petroleum diesel can help in controlling air pollution and easing the pressure on scarce resources without significantly sacrificing engine power and economy. Jinlin Xue explained in his paper “Combustion characteristics, engine performances and emissions of waste edible oil biodiesel in diesel engine attempts to cite and analyze highly rated journals in scientific indexes about combustion characteristics, engine power, economy, regulated emissions and non-regulated emissions of waste edible oils (WEO) biodiesels on diesel engine. The use of WEO biodiesels leads to the slight difference in combustion characteristics such as ignition delay, rate of pressure rise, peak pressure and heat release rate, and the substantial reduction in PM, HC and CO emissions accompanying with the imperceptible power loss, the increase in fuel consumption and NO_x emission on conventional diesel engines with no or fewer modification, compared to diesel. Although the inconsistent conclusions have been made on CO2 emission of biodiesels from WEO, it reduces greatly from the view of the life cycle circulation of CO2. For non-regulated emissions, the reduction appears for PAH emissions but carbonyl compounds emissions have discordant results for WEO biodiesels. Therefore, WEO biodiesels have the similar combustion characteristics, engine performances and emissions to that of biodiesels from food-grade oils, and the blends of WEO biodiesel with small content by volume could replace the petroleum-based diesel fuel to help in controlling air pollution, encouraging the collection and recycling of waste edible oil to produce biodiesels and easing the pressure on scarce resources to a great extent without significantly sacrificing engine power, economy and emissions. A.M. Liaquat, M. Shahabuddin explained in their paper Effect of Coconut Biodiesel Blended Fuels on Engine Performance and Emission Characteristics have shown the engine performance parameters and emissions characteristics for direct injection diesel engine using coconut biodiesel blends without any engine modifications. A total of three fuel samples, such as DF (100% diesel fuel), CB5 (5% coconut biodiesel and 95% DF), and CB15 (15% CB and 85% DF) respectively were used. Engine performance test were been carried out at 100% load, keeping throttle 100% wide open with variable speeds of 1500 to 2400 rpm at an interval of 100 rpm. Whereas, engine emission tests were carried out at 2200 rpm at 100% and 80% throttle position. There has been a decrease in torque and brake power, while increase in specific fuel consumption has been observed for biodiesel blended fuels over the entire speed range compared to net diesel fuel. In case of engine exhaust gas emissions, lower HC, CO and, higher CO2 and NOx emissions have been found for biodiesel blended fuels compared to diesel fuel. Moreover, reduction in sound level for both biodiesel blended fuels has been observed when compared to diesel fuel. Therefore, it can be concluded that CB5 and CB15 can be used in diesel engines without any engine modifications and have beneficial effects both in terms of emission reductions and alternative petroleum diesel fuel. H. Raheman, S.V. Ghadge, explained in their paper "Performance of compression ignition engine with mahua (*Madhuca indica*) biodiesel" reported the performance of biodiesel obtained from mahua oil and its blend with high speed diesel in a Ricardo E6 engine has been presented with some of its fuel properties. These properties were found to be comparable to diesel and confirming to both the American and European standards. Engine performance (brake specific fuel consumption, brake thermal efficiency and exhaust gas temperature) and emissions (CO, smoke density and NO*x*) were measured to evaluate and compute the behavior of the diesel engine running on biodiesel. The reductions in exhaust emissions and brake specific fuel consumption together with increase brake power, brake thermal efficiency made the blend of biodiesel (B20) a suitable alternative fuel for diesel and thus could help in controlling air pollution. Ekrem Buyukkaya explained in their paper "Effects of biodiesel on a DI diesel engine performance, emission and combustion characteristics have investigated to evaluate the performance, emission and combustion of a diesel engine using neat rapeseed oil and its blends of 5%, 20% and 70%, and standard diesel fuel separately. The results indicate that the use of biodiesel produces lower smoke opacity (up to 60%), and higher brake specific fuel consumption (BSFC) (up to 11%) compared to diesel fuel. The measured CO emissions of B5 and B100 fuels were found to be 9% and 32% lower than that of the diesel fuel, respectively. The BSFC of biodiesel at the maximum torque and rated power conditions were found to be 8.5% and 8% higher than that of the diesel fuel, respectively. From the combustion analysis, it was found that ignition delay was shorter for neat rapeseed oil and its blends tested compared to that of standard diesel. The combustion characteristics of rapeseed oil and its diesel blends closely followed those of standard diesel. Md. Nurun Nabi, Md. Mustafizur Rahman, Md. Shamim Akhter explained in their paper "Biodiesel from cotton seed oil and its effect on engine performance and exhaust emissions" have shown that exhaust emissions including carbon monoxide (CO) particulate matter (PM) and smoke emissions were reduced for all biodiesel mixtures. However, a slight increase in oxides of nitrogen (NOx) emission was experienced for biodiesel mixtures. Seung Hyun Yoon and Chang Sik Lee explained in their paper "Experimental investigation on the combustion and exhaust emission characteristics of biogas–biodiesel dual-fuel combustion in a CI engine" showed that the combustion characteristics of single-fuel combustion for biodiesel and diesel indicated the similar patterns at various engine loads. In dual-fuel mode, the peak pressure and heat release for biogas–biodiesel were slightly lower compared to biogas–diesel at low load. At 60% load, biogas–biodiesel combustion exhibited the slightly higher peak pressure, rate of heat release (ROHR) and indicated mean effective pressure (IMEP) than those of diesel. Also, the ignition delay for biogas–biodiesel indicated shortened trends compared to ULSD dual-fueling due to the higher cetane number (CN) of biodiesel. Significantly lower NO_x emissions were emitted under dual-fuel operation for both cases of pilot fuels compared to single-fuel mode at all engine load conditions. Also, biogas–biodiesel provided superior performance in reductions of soot emissions due to the absence of aromatics, the low sulfur, and oxygen contents for biodiesel

2. MATERIALS USED

2.1 EXTRACTION OF KARANJA OIL

For oil extraction from kernel of karanja two methods were implemented. First one was the mechanical extraction and second one was the chemical extraction means solvent extraction. In mechanical process, the seeds were expelled in a mechanical expeller which was available in the Integrated Biodiesel Plant. The oil recovery was calculated to be near about 27%.We extracted (200 – 250) ml of oil by grinding 1kg of karanja seeds. The extracted karanja oil contains free fatty acids, phospholipids, sterols, water odorants and other impurities. All the crude karanja oil was having high viscosity value. In order to use straight vegetable oil (SVO) in the engine, viscosity was to be reduced which can be done by heating the above oil. Other problems associated with using it directly in engine include carbon deposits, oil ring sticking, lubricating problem and also formation of deposits in the engine due to incomplete combustion. In order to reduce viscosity, four techniques were adopted like pyrolysis, dilution, micro emulsification and transesterification. Currently we adopt transesterification technique to convert high FFA and high viscous fluid to low FFA and low viscous fuel, namely karanja biodiesel. A fixed mass of fresh karanja seeds are taken and put into the expellers for oil extraction purpose. Two expellers are arranged in a series for this process. The fresh seeds filled with karanja oil are crushed by the rollers provided in the first expeller and cakes are formed. After the cake formation the outputs are fed to the second expeller. In second expeller extracts karanja oil from the cakes with particulate impurities. Then the extracted karanja oil undergoes filterization process. In this process the crude karanja oil is impinged on a semitransparent film or fine net and the karanja oil with soluble impurities is collected. Then the expelled oil is drawn into a chemical mixture where the oil is blended with some appropriate agents. External power source is used for these processes and is regulated under guidance. Then the blended karanja oil is taken into the reactor unit. In the reactor unit the oil is kept in a particular temperature and pressure for minimum 24 hours. Inside the reactor unit the soluble impurities are separated from the blended fluid. The containers of the reactor units are provided pipes and control valves at the bottom. Now the pure karanja oil is drawn out by the control valve and the soluble impurities are left in the container.

Layout of Experiment



2.2 EXPERIMENTAL PROCEDURE FOR PRODUCTION OF BIO-FUEL

Reaction or transesterification was carried out in a system, as shown in figure .reactor consisted of spherical flask, which was put in side the heat jacket .oil was used as medium of heat transfer from heat jacket to the reactor. Thermostat was a part of heat jacket, which maintained the temperature of oil and in term the temperature of the reactance at a desired value. The reaction was carried out at around (65-70) ˚c. Spherical flask consists of 4 openings. The centre 1 was used for putting starrer in the reactor. The motor propelled the starrer .Thermometer was put in side the 2nd opening to continuously monitor the temperature of the reaction. Alcohol being volatile vaporized during the reaction. So the condenser was put in the 3rd opening to reflux the vapour back to the reactor to prevent any reactant loss.4th opening was used for filling reactants to the reactor.

Fig.1.1 Experimental unit

2.3 ESTERIFICATION

Karanja oil contains 6%- 20% (by wt) free fatty acids26-29. The methyl ester is produced by chemically reacting karanja oil with an alcohol (methyl), in the presence of catalyst (KOH). A two stage process was used for the transesterification of karanja oil .The first stage (acid catalyzed) of the process was to reduce the free fatty acids (FFA) content in karanja oil by esterification with methanol (99% pure) and acid catalyst sulphuric acid (98% pure) in one or one half hour time at 60°C in a closed reactor vessel. The karanja crude oil was first heated to 45-50 °C and 1% (by wt) sulphuric acid was to be added to oil. Then methyl alcohol about (22-25) % (by wt) was added. Methyl alcohol was added in excess amount to speed up the reaction. This reaction was proceed with stirring at 700 rpm and temperature was controlled at 55-60oC for 90 min with regular analysis of FFA every after 25-30 min. When the FFA was reduced up to 1%, the reaction was stopped. The major obstacle to acid catalyzed esterification for FFA is the water formation. Water can prevent the conversion reaction of FFA to esters from going to completion. After dewatering the esterified oil, it was fed to the transesterification process.

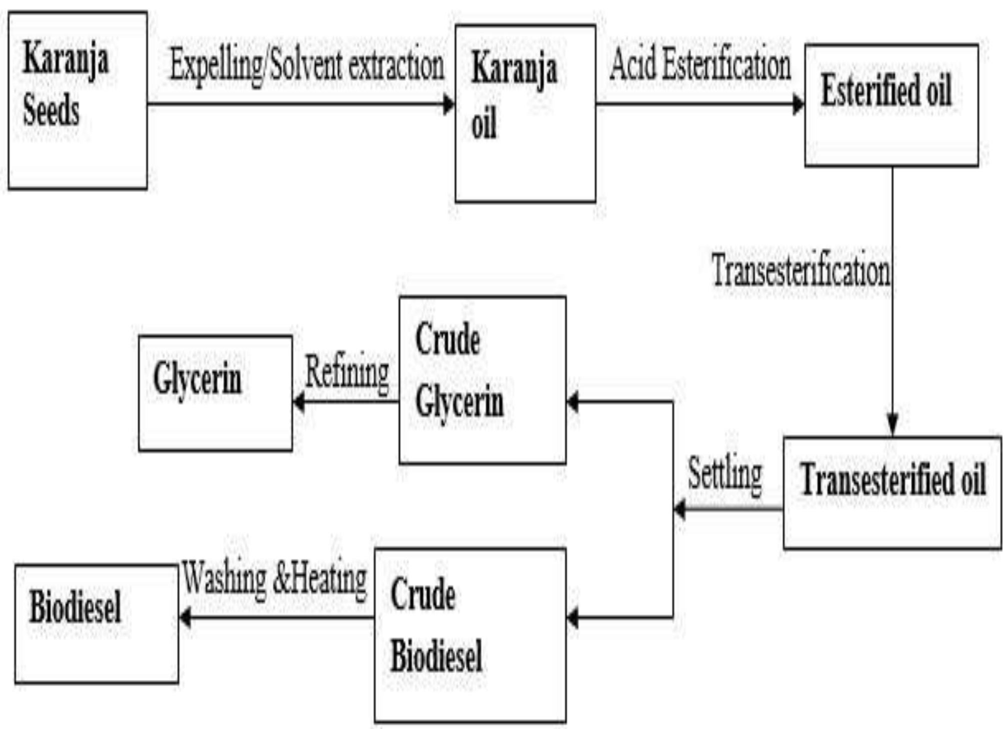
Fig: 1.2 Esterification Process

2.4 CATALYZED REACTION MIXING OF ALCOHOL CATALYST

The catalyst used is typically sodium hydroxide (NaOH) with 1% of total quantity of oil mass. It was dissolved in the 13% of distilled methanol (CH_3OH) using a standard agitator at 700 rpm speed for 20 minutes. The alcohol catalyst solution was prepared freshly in order to maintain the catalytic activity and prevent the moisture absorbance. After completion it was slowly charged into preheated esterified oil. The quantity of chemicals used and time for both the reaction are given in observation

2.5 TRANSESTERIFICATION REACTION

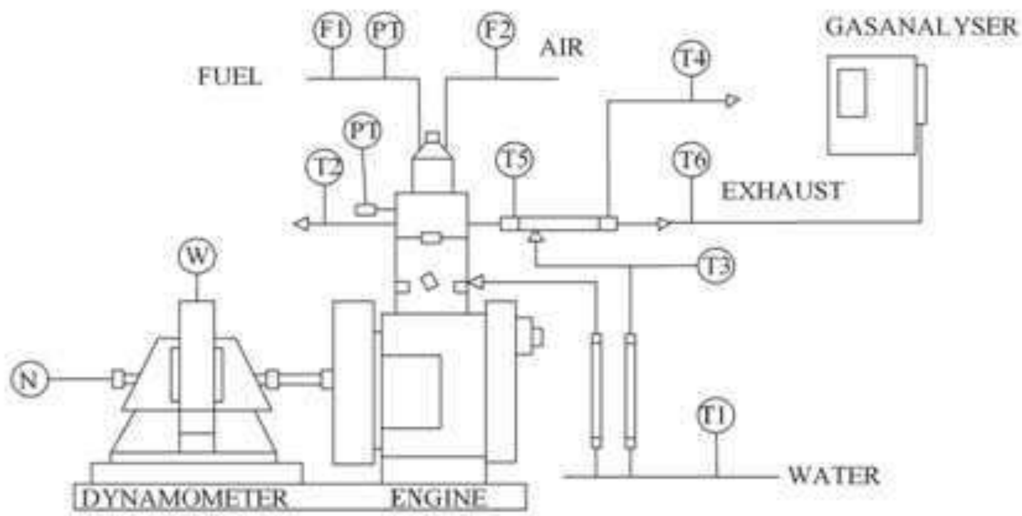
When the methaloxide was added to oil, the system was closed to prevent the loss of alcohol as well as to prevent the moisture. The temperature of reaction mix was maintained at 60 to 65oC (that was near to the boiling point of methyl alcohol) to speed up the reaction. The recommended reaction time is 70 min. The stirring speed was maintained at 560-700rpm. Excess alcohol is normally used to ensure total conversion of the fat or oil to its esters. The reaction mixture was taken each after 20 min. for analysis of FFA. After the confirmation of completion of methyl ester formation, the heating was stopped and the products were cooled and transferred to separating funnel.



3. EXPERIMENTAL WORK

Biodiesel Purification

After pumping the last glycerol phase out, the formed biodiesel may still contain traces of ions such as potassium, sodium, magnesium, calcium, glycerol residue, sediments and other solids. All these impurities must be removed, along with any water that might still be present after the reaction. After settling and glycerol draining, biodiesel is passed through a 9,512 rpm separator for glycerol separation. Then a cleaning agent, named ACA90, containing an inorganic chelating agent combines with impurities in the biodiesel to produce large, dense gum-like complexes which are then removed by a separator. Actually, within the separator the force of gravity is replaced by centrifugal forces, which can be thousands of times greater, and consequently achieving in few seconds the separation which could take many hours in a tank under the influence of gravity. Finally, the washed biodiesel undergoes vacuum evaporation to remove excess water, and an ant oxidation agent is added to improve the biodiesel oxidative stability.



Then, the moisture free biodiesel is pumped to the biodiesel storage tank through a 0.8µm pore size cellulose cartridge filter to remove any residual solid particles.

Fig 1.3 Schematic diagram of experimental

F1 & F2:		Flow sensor for fuel and air
W	:	Load sensor
N	:	Engine speed sensor
PT	:	Cylinder pressure & Injection pressure sensor
T1-6	:	Temperature sensors

Fig1.4 Experimental setup of C.I. Engine

Table 1.2 Engine setup specifications

Engine manufacturer	Apex Innovations (Research Engine test set up)
Software	Engine soft Engine performance analysis software
Engine type	Single cylinder four stroke multi fuel research engine
No. of cylinder	1
Type of cooling	Water cooled
Rated power	3.5 kW @ 1500 rpm
Cylinder diameter	87.5 mm
Orifice diameter	20 mm
Stroke length	110 mm
Connecting rod length	234 mm
Dynamometer	Type: eddy current, water cooled, with loading unit

Exhaust gas analyzer specifications

Exhaust Gas Analyzer is used to measure the level of pollutants in the exhaust of the car. Exhaust Gas Analyzer is also used to tune an engine for optimum mileage. Exhaust Gas Analyzer is also applicable to measure the function of catalytic converters. Exhaust Gas Analyzer is available with an in built 20- Column printer. Exhaust Gas Analyzer is used in various governments authorized test centers.

Fig1.5 Exhaust gas analyzer

Emission parameters	Measurement
Carbon Monoxide (CO)	0 – 10% vol.
Hydrocarbons (HC)	0 – 20000 ppm
Nitrogen Oxide (NOx)	0 – 5000 ppm

Table 1.3 Compositions of Batches

Sr. No	Batch Code	Karanja Oil %	Diesel %
1	K0	0	100
2	K10	10	90
3	K20	20	80
4	K40	40	60

5	K60	60	40
6	K80	80	20
7	K100	100	0

4. RESULTS AND DISCUSSION

The Table 1.3 indicates the compositions of different batches with variation of different % of karanja oil. Fig. 1.7 shows the variation of mechanical efficiency in case of diesel, K10, K20, K40, K60 and K80 increase with increase in load for all prepared test fuels. Similarly the Fig. 1.9 shows the variation of Break thermal efficiency in case of diesel, K10, K20, K40, K60 and K80 increase with increase in load for all prepared test fuels. It is clearly seen that the fuel consumption of diesel, K10, K20, K40, K60 and K80 increase with increase in load for all prepared test fuels. From the present test results it is observed that diesel has highest brake thermal efficiency than that of other test fuels which is because of its higher heat content, lower viscosity, lower density and higher volatility in comparison to Karanja oil. However, increasing the percent of additive with biodiesel the Break Thermal Efficiency increases with respect to load and shows very close behaviour to that of diesel because of increase in heat content, reduction in viscosity, density and increase in volatility which leads to better combustion of the test fuels. Fig. 1.10 shows the variation in Brake specific fuel consumption (BSFC) for diesel, K10, K20, K40, K60 and K80. It is observed that BSFC decreases for all the test fuels with increase in load. It is seen that BSFC is highest for pure biodiesel and lowest for diesel because of high viscosity, density, low volatility and low heat content of pure biodiesel when compared with that of diesel.

Comparisons of performance parameters vs. load on different blends of Karanja fuels

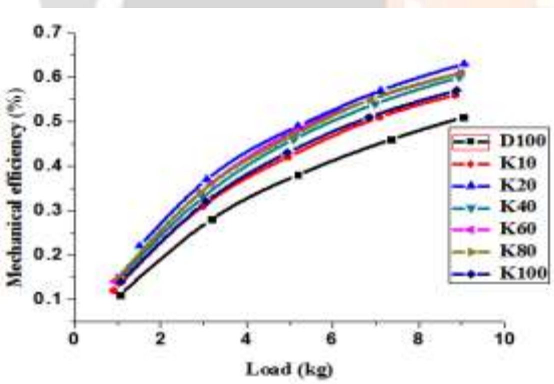


Fig: 1.7 Mechanical efficiency vs. load with different blends of karanja oil

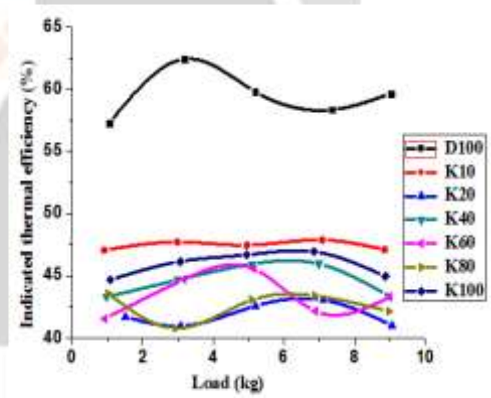


Fig: 1.8 Indicated thermal efficiency vs. load with different blends of karanja oil

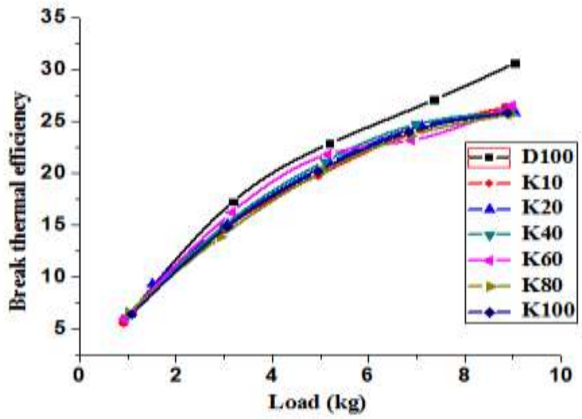


Fig: 1.9 Break thermal efficiency vs. load with different blends of karanja oil

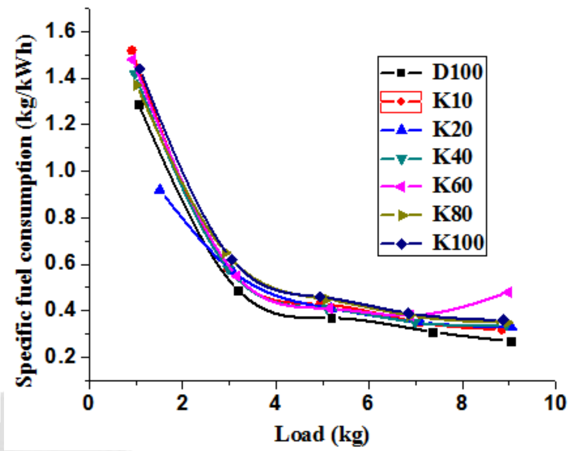


Fig: 1.10 Specific fuel consumption vs. load with different blends of karanja oil

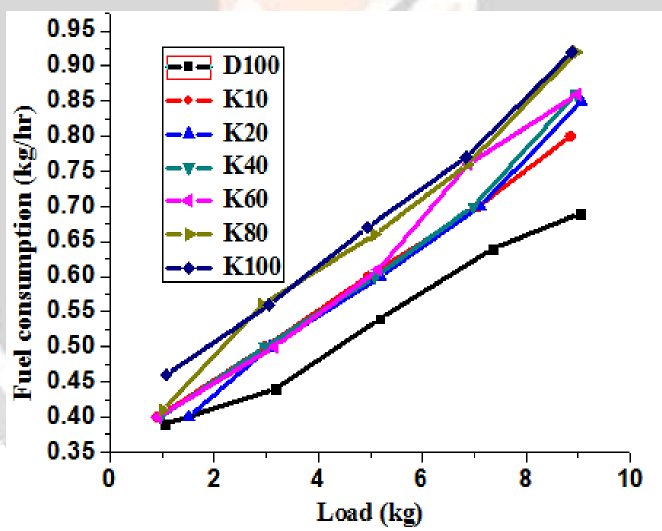


Fig: 1.11 Fuel consumption v/s. load with different blends of karanja oil

Sample Calculations

- (For 1 kg load at Constant speed 1500 rpm of a Diesel engine when working on diesel fuel and Palm oil blend **D90 P10**)
- Find the density of diesel and Palm oil blend of **D90 K10**.

$$\frac{volume\text{ of diesel } V_D}{volume\text{ of karanja oil } Vp} = \frac{\rho_{karanja\ oil} - \rho_{\text{blend}}}{\rho_{blend} - \rho_{Diesel}}$$

$$\therefore \frac{90}{10} = \frac{860 - \rho_{blend}}{\rho_{blend} - 833}$$

$$\therefore \rho_{blend} = 835.7 \text{ Kg/m}^3 = 0.8357 \text{ Kg/ lit}$$

❖ Find the calorific value of diesel and palm oil blend of **P10**.

Brake Power

$$BP = \frac{2\pi NT}{1000 * 60} KW$$

BP = 2Π*1547*1.65/ (60000)

= 0.26 kW

Where,

N = Brake Speed, rpm = 1547 rpm

T = Torque, n-m

$= (1 * 9.81) * 0.185\ Nm$

= (1*9.81)* 0.185

=1.65 Nm

1. Fuel Consumption

 Let time required for 10 ml fuel be t_f sec & density of blend is 0.8357 kg/lit

 $FC = \frac{10}{t_f} * \frac{3600}{1000} * 0.8357$

 FC = 0.39984

 FC = 0.39984 kg/hr

2. Specific Fuel Consumption

 $SFC = \frac{FC}{BP}\ Kg/KWH$

 SFC = 0.39984 / 0.26

 SFC = 1.52 kg/kWh

3. Heat Supplied By Fuel

 $H_F = FC * 42247.98\ KJ/hr$

 Hf = 0.39984*42247.98Hf = 16892.43 kJ/hr

 Where, calorific value of blend of **P10** is 42247.98 kJ/kg.

4. Plot the graph of FC v/s BP for different readings. Extend the line to meet zero FC. The power (on negative side) at which FC is zero is friction power, FP. The plot is known as Willian's Line. FP = 1.955307 kW (from graph)

5.

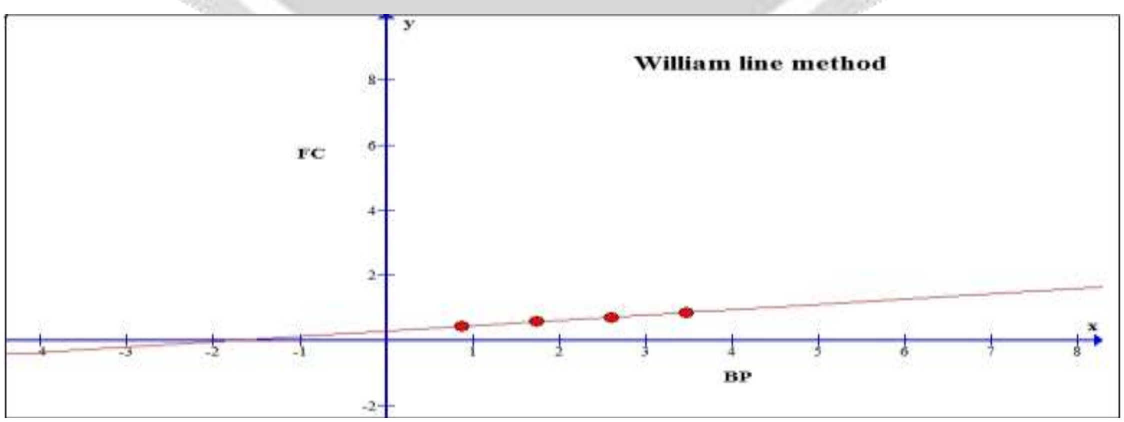


Fig.1.6 Williams line method

Indicated Power,

$IP = FP + BP$ KW
IP = 1.95 + 0.26 = 2.22 kW

6. Heat Equivalent To Bp
$H_{BP} = BP * 3600$ kJ/hr
H_{BP} = 0.26*3600
= 936 kJ/hr

7. Heat Equivalent To IP,
$H_{IP} = IP * 3600 \frac{kJ}{hr}$
H_{IP} = 2.22 * 3600
= 7992 kJ/hr

8. Efficiency,
i) Mechanical Efficiency
$$\eta_m = \frac{BP}{IP} * 100\%$$
= (0.26/2.22)*100)
= 12.11%

ii) Brake Thermal Efficiency,
$$\eta_{BT} = \frac{\text{HEAT IN BP}}{\text{HEAT SUPPLIED BY FUEL}} * 100\%$$
= (0.26*100) / 0.39984/3600*42247.98
= 5.60%

Other calculation is to be finding out by similar way at different load and different blend.

Variations in HC emission at different load conditions for diesel and karanja biodiesel are shown in fig. 1.12. It is seen that unburnt hydrocarbon emission increases with that of load for all prepared test fuels. From fig.1.12 it is understood that biodiesel produces less HC emission in comparison to that of diesel because of better combustion of the test fuel and its blend with additive due to presence of oxygen. HC emission for diesel, K10, K20, K40, K60 and K80 increase with increase in load for all prepared test fuels. Fig. 1.13 shows the variation in CO emission with respect to variation in load. It is observed that CO emission decrease with increase in load for all prepared test fuels. CO emission is highest for pure biodiesel because of poor spray characterization that results in improper combustion which gives rise to CO formation.

Comparisons of emission parameters vs. load on different blend of karanja fuels

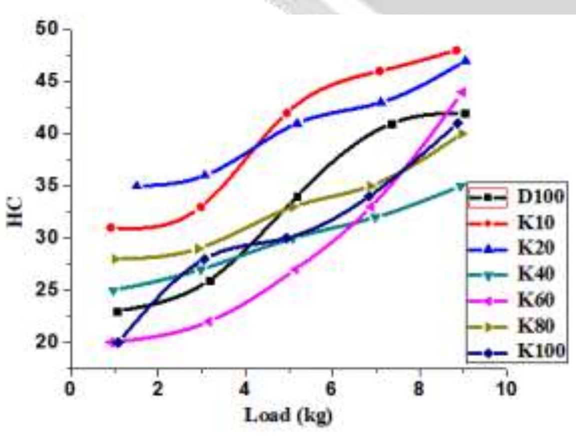


Fig: 1.12 HC vs. load with different blends of karanja oil

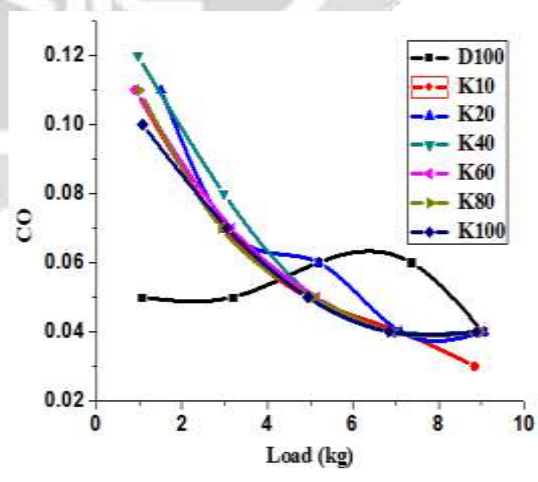


Fig: 1.13 CO vs. load with different blends of karanja oil

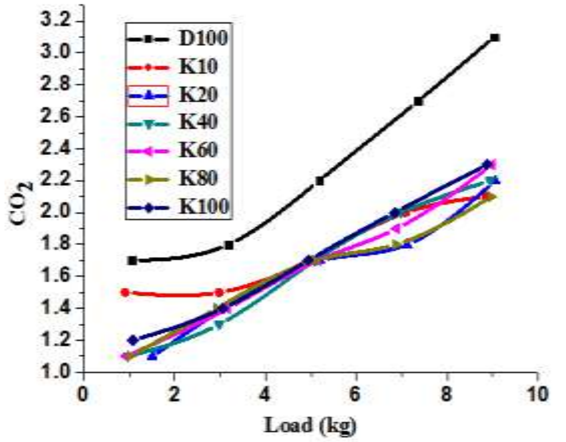


Fig: 1.14 CO2 vs. load with different blends of karanja oil

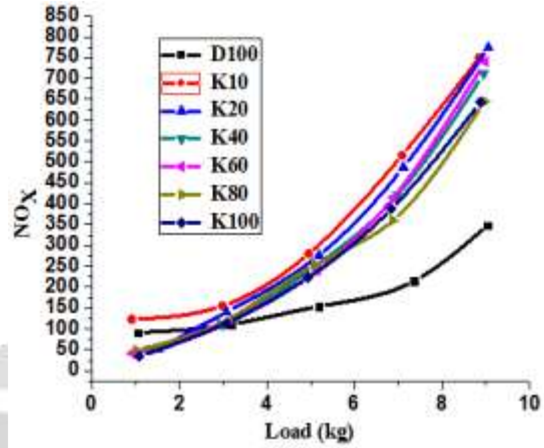


Fig: 1.15 NOx vs. load with different blends of karanja oil

Fig. 1.15 exhibits the variation in NOx emission with load for diesel, K10, K20, K40, K60 and K80. From the literature it is revealed that NOx is directly proportional to power output of the engine because NOx emission increases with increase in combustion and exhaust temperature. The present test results show that NOx emission increases almost linearly with increase in engine load which is because of higher cylinder pressure and temperature at higher loads. It is found highest for pure biodiesel because of high oxygen content which results in complete combustion causing high combustion temperature.

5. CONCLUSION

During the present investigation several tests were carried out on a four stroke single cylinder injection diesel engine using diesel and karanja biodiesel at different proportions. From the experimentation following conclusions were drawn.

1. Mechanical efficiency in case of diesel, K10, K20, K40, K60 and K80 increase with increase in load for all prepared test fuels. Brake specific fuel consumption is highest for pure biodiesel at all loads because of high density, high volatility and low heat content of biodiesel.
2. Brake specific fuel consumption (BSFC) for diesel, K10, K20, K40, K60 and K80 results decreases for all the test fuels with increase in load. BSFC decreases because of better combustion. Exhaust gas temperature is found highest for pure biodiesel. This may be due to high combustion temperature of biodiesel because of high oxygen content.
3. Hydrocarbon emission increases with that of load for all prepared test fuels. it is understood that biodiesel produces less HC emission in comparison to that of diesel because of better combustion of the test fuel and its blend with additive due to presence of oxygen. HC emission for diesel, K10, K20, K40, K60 and K80 increase with increase in load for all prepared test fuels.
4. It is observed that CO emission decrease with increase in load for all prepared test fuels. CO emission is highest for pure biodiesel because of poor spray characterization that results in improper combustion which gives rise to CO formation.

References

1. Jinlin Xue, Tony E. Grift, Alan C. Hansen et. al. "Effect of biodiesel on engine performances and emissions "Renewable and Sustainable Energy Reviews, Volume 15, Issue 2, February 2011, Pages 1098–1116.
2. Jinlin Xue, Combustion characteristics, engine performances and emissions of waste edible oil biodiesel in diesel engine. Renewable and Sustainable Energy Reviews. Volume 23, July 2013, Pages 350–365.

3. A.M. Liaquat, M. Shahabuddin "Effect of Coconut Biodiesel Blended Fuels on Engine Performance and Emission Characteristics "Procedia Engineering Volume 56, 2013, Pages 583–590 5th BSME International Conference on Thermal Engineering.
4. H. Raheman, S.V. Ghadge Performance of compression ignition engine with mahua *(*Madhuca indica*)* biodiesel. Fuel Volume 86, Issue 16, November 2007, Pages 2568–2573.
5. Ekrem Buyukkaya. Effects of biodiesel on a DI diesel engine performance, emission and combustion characteristics. Fuel Volume 89, Issue 10, October 2010, Pages 3099–3105.
6. Ekrem Buyukkaya. Effect of biodiesel on a DI diesel engine performance, emission and combustion characteristics. Fuel 89 (2010) 3099-3105.
7. Hansen AC, Zhang Q, Lyne PWL. Ethanol–diesel fuel blends – a review. Bioresource Technol 2005; 96:277–85.
8. Ecklund EE, Bechtold RL, Timbario TJ, McCallum PW. State-ofthe-art report on the use of alcohols in diesel engines. SAE paper no. 840118; 1984.
9. Rakopoulos DC, Rakopoulos CD, Kakaras EC, Giakoumis EG. Effects of ethanol– diesel fuel blends on the performance and exhaust emissions of heavy duty DI diesel engine. Energy Convers Manage 2008; 49:3155–62.
10. Miers SA, Carlson RW, McConnell SS, Ng HK, Wallner T, Esper JL. Drive cycle analysis of butanol/diesel blends in a light-duty vehicle. SAE paper no. 2008- 01-2381; 2008.
11. Hansen AC, Kyritsis DC, Lee CF. Characteristics of biofuels and renewable fuel standards. In: VertesBlaschek AA, Blaschek HP, Yukawa H, Qureshi N, editors. Biomass to biofuels – strategies for global industries. New York: John Wiley; 2009.
12. Graboski MS, McCormick RL. Combustion of fat and vegetable oil derived fuels in Diesel engines. Prog Energy Combust Sci 1998; 24:125–64.
13. Demirbas A. Biodiesel fuels from vegetable oils via catalytic and non-catalytic supercritical alcohol transesterifications and other methods: a survey. Energy Convers Manage 2003; 44:2093–109.
14. Rakopoulos CD, Antonopoulos KA, Rakopoulos DC, Hountalas DT, Giakoumis EG. Comparative performance and emissions study of a direct injection diesel engine using blends of diesel fuel with vegetable oils or bio-diesels of various origins. Energy Convers Manage 2006; 47:3272–87.
15. Bueno AV, Velasquez JA, Milanez LF. Heat release and engine performance effects of soybean oil ethyl ester blending into diesel fuel. In: Proceedings of the 22nd International Conference on 'ECOS 2009', Foz do Iguacu/Parana, Brazil, August 31– September 3; 2009. p. 2009–18.
16. Qi DH, Geng LM, Chen H, Bian YZH, Liu J, Ren XCH. Combustion and performance evaluation of a diesel engine fuelled biodiesel produced from soybean crude oil. Renew Energy 2009; 34:2706–13.
17. Nabi N, Akhter S, Shahadat MZ. Improvement of engine emissions with conventional diesel fuel and diesel–biodiesel blends. Bioresour Technol 2006;97:372–8.
18. Last RJ, Kruger M, Durnholz M. Emissions and performance characteristics of a 4-stroke, direct injected diesel engine fuelled with blends of biodiesel and low sulphur diesel fuel. SAE paper, no. 950054; 1995.
19. Lapuerta M, Armas O, Rodriguez-Fernandez J. Effect of biodiesel fuels on engine emissions. Prog Energy Combust Sci 2008; 34:198–223.
20. Nabi N, Rahman M, Akhter S. Biodiesel from cotton seed oil and its effect on engine performance and exhaust emissions. Appl herm Eng 2009; 29:2265–70.
21. Zheng M, Mulenga MC, Reader GT, Wang M, Ting DSK, Tjong J. Biodiesel engine performance and emissions in low temperature combustion. Fuel 2008;87(6):714–22.
22. Tree DR, Svensson KI. Soot processes in compression ignition engines. Prog Energy Combust Sci 2007; 33:272–309.
23. Senthil KM, Kerihuel A, Bellettre J, Tazerout M. Experimental investigations on the use of preheated animal fat as fuel in a compression ignition engine. Renew Energy 2005; 30:2314–23.
24. Devan PK, Mahalakshmi NV. Study of the performance, emission and combustion characteristics of a diesel engine using poon oilbased fuels. Fuel Process Technol 2009; 90:513–9.
25. Devan PK, Mahalakshmi NV. Performance, emission and combustion characteristics of poon oil and its blends in a DI diesel engine. Fuel 2009; 88:861–7.
26. Ozsezen AN, Canakci M, Turkcan A, Sayin C. Performance and combustion characteristics of a DI diesel engine fueled with waste palm oil and canola oil methyl esters. Fuel 2009; 88:629–36.
27. Canakcı M, Ozsezen AN, Turkcan A. Combustion analysis of preheated crude sunflower oil in an IDI diesel engine. Biomass Bioenergy 2009; 33:760–7.

28. Maria U. Alzueta, Hanne Røjel, Per G. Kristensen, Peter Glarborg, and Kim Dam-Johansen. Laboratory study of the co/nh3/no/o2 system: implications for hybrid reburn/sncr strategies. Energy & Fuels 1998 12(5) PP1001-1007.
29. Diesel Engine Performance And Emission Analysis Using Biodiesel From Various Oil Sources - Review (Gaurav Dwivedi , Siddharth Jain , M.P. Sharma.) Alternate Hydro Energy Centre, Indian Institute of Technology Roorkee, Roorkee, Uttarakhand- 247667, India.
30. "Biofuels (Alcohols And Biodiesel) Applications As Fuels For Internal Combustion Engines" By Avinash Kumar Agarwal (Aug 2006) , Department Of Mechanical Engineering, Indian Institute Of Technology Kanpur, Kanpur-208 016, India
31. Performance And Emission Characteristics Of Diesel Engine Running On Blended Palm Oil" By A.M. Iqbal, Z.A. Zainal, M. Mazlan, A.M. Mustafa Al-Bakri, M.S. Salim (Aug 2015)
32. "Determination Of Performance Characteristics Of Petrol/Bio-Ethanol Blends For Spark Ignition (Si) Engines" By S.T Ubwa , B.A Oshido, S.P Malu (Jan 2014) Corresponding Author; S.T Ubwa, Department Of Chemistry, Benue State University, P.M.B 102119 Makurdi, Nigeria.
33. Performance And Emission Characteristics Of Different Blends Of Linseed Methyl Ester On Diesel Engine" By S.K. Mahla And Arvind Birdi (April 2012) Department Of Mechanical Engineering, Ggs College Of Modern Technology, Kharar, (Mohali), (Pb), India
34. Parametric Optimization of Single Cylinder Diesel Engine For Pyrolysis Oil And Diesel Blend For Specific Fuel Consumption Using Taguchi Method" By Mr. Krunal B Patel, Prof. Tushar M Patel, Mr. Saumil C Patel (Apr 2013) L.D.R.P Engineering College, Gandhinagar, India.
35. Emission And Performance Characteristics of Karanja Biodiesel and Its Blends in a C.I. Engine And It's Economics" By Nagarhalli M. V., Nandedkar V. M. And Mohite K.C. (Fab 2010)
36. "Performance And Exhaust Emission Analysis Of Direct Injection Diesel Engine Using Pongamia Oil" By S. Ghosh , D. Dutta (Dec 2012) Asst Prof., Camellia School Of Engineering & Technology, Barasat, Kolkata - 700124, W.B., India.
37. "Studies on the Properties of Karanja Oil for Probable Industrial Application" By Prof. R. K. Patel. Department Of Chemistry National Institute Of Technology, Rourkela Rourkela-769008
38. Performance & Emission Analysis of Blends of Karanja Methyl Ester In A Compression Ignition Engine" By Prof. (Dr.) R.K.Singh. National Institute Of Technology Rourkela Orissa-769008