PERFORMANCE OF DIESEL ENGINE USING JATROPHA CURCAS BIO-DIESEL

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Abstract

The increasing industrialization and development in the field of transport sector of the world have led to a steep rise for the demand of petroleum products. Petroleum fuels are obtained from limited reserves of foreign countries. Presently our country is facing the problem of foreign exchange due to the import of crude oil. Hence, it is necessary to look for alternative fuel, which can be produced from available raw material within the country.

In the present investigation, the bio-diesel produced from the jatropha seeds have been considered as a potential alternative for running the compression ignition engines. The different blends of bio-diesel and conventional diesel have been tested on the engine. The experimental data obtained for various concentrations of bio-diesel blends have been compared with base line data of conventional diesel. Significant improvement in engine performance has been observed due to the use of bio-diesel. Acceptable thermal efficiencies of the engine have been obtained with different blends of bio-diesel and diesel.

It has been observed that 20% of jatropha oil can be substituted for diesel without any engine modification and preheating of the blends.

***Keywords**: Jatropha curcas, oil, bio-diesel, viscosity, diesel, compression ignition engine*

1. Introduction

The world is presently facing the problems of depletion of fossil fuel and environmental degradation due to over use of underground based carbon resources. The search for an alternative fuel is the urgent need of present problems.

The fuels of bio-origin such as alcohol, vegetable oil, bio-mass and biogas can be used directly in agricultural and transportation sector. Bio fuels are abundantly available alternative fuels, and have the potential to be produced from bio-mass sources. These fuels can be used in diesel engine by preparing bio-diesel. Trans-esterification process utilizes methanol or ethanol oils as the process inputs.

The inventor of the diesel engine, Rudolf Diesel used peanut oil as a diesel fuel in 1985. But higher viscosity was found responsible for various undesirable combustion properties of neat vegetable oil. Knothe [1] investigated the influence of fatty acid and structure on the performance of diesel fuel. Hemmerlein et al [2] tested different engines using rapeseed oil and found the higher emissions of aromatic, aldehydes, ketones, particulate etc. Many researchers had used vegetable oils as fuel in the diesel engine but it could not be successfully implemented. In the present paper, bio-diesel obtained from jatropha seed have been used for experimental work which is locally available with less cost.

In future, bio-diesel obtained from karanj, mahua, neem, castor oil etc can be tested on engine. It will be helpful in reducing our dependency on petro fuel.

2. Trans-esterification Process

A laboratory-scale biodiesel reactor of one-liter capacity was developed for the production of biodiesel from Jatropha curcus oil by the alkali-catalysed transesterification method. Methanol was chosen as the alcohol used for the transesterification of Jatropha curcus oil because of its low cost and the alkaline catalyst sodium hydroxide (NaOH) was chosen since it is cheaper and reacts much faster than acid catalysts.

The important factors that affect the transesterification reaction are the amounts of methanol and sodium hydroxide, reaction temperature and reaction time. The molecular weight of Jatropha curcus oil with major chemical constituents was determined as 870. Since the oil also contains other minor constituents, the approximate molecular weight of Jatropha curcus oil was taken as 900. As per the transesterification reaction, 3 moles of methanol were required to react with 1 mole of vegetable oil. The molecular weight of methanol is 32 and hence 96 gms of methanol were required for the transesterification of 1 mole (or 900 grams) of Jatropha curcus oil, which amounted to 10.67% methanol.

In order to optimize the amount of methanol required for the reaction, experiments were conducted with four different percentages of methanol (10, 15, 20 and 25%), keeping the catalyst concentration, reaction temperature and reaction time constant.

Most researchers have used 0.1 to 1.2% (by weight of oil) of NaOH for bio-diesel production. If acid value is greater than 1, more NaOH is required to neutralize free fatty acids. In the present study, three different catalyst concentrations were used (0.5, 1.0 and 1.5% NaOH), keeping methanol concentration, reaction temperature and reaction time constant in order to optimize the concentration of NaOH. For the preparation of sodium methoxide solution, sodium hydroxide (NaOH) pellets were completely dissolved in methanol and added into the oil, since NaOH pellets would react with CO2 and water present in the atmosphere and yield sodium carbonate, which would affect the performance of the catalyst during the trans-esterification reaction.

The reaction temperature influences the reaction rate and the yield of esters. The reaction temperature should always be maintained below the boiling point (65ºC) of methanol. Hence for the trans-esterification of *Jatropha curcus* oil with methanol, three different temperatures were used (30, 45 and 60ºC), keeping alcohol and catalyst concentrations and reaction time constant in order to optimize the reaction temperature.

The methyl ester conversion rate increases with the reaction time. Different researchers have reported different reaction times for the trans-esterification process. The process required 3 to 4 hours for making ester and the reaction mixture was stirred for 90 min before it was transferred to a separation funnel. Hence four different reaction times were selected for the process of trans-esterification of *Jatropha curcus* oil (30, 60, 90 and 120 min), keeping alcohol and catalyst concentrations and reaction temperature constant in order to optimize the reaction time.

The following experimental procedure was adopted for the production of bio-diesel. Some 200 grams of *Jatropha curcus* oil was taken in a three-necked round-bottomed flask. A water-cooled condenser and a thermometer with cork were connected to the side openings on either side of the round-bottomed flask. The required amount of catalyst NaOH was weighed and dissolved completely in the required amount of methanol by using a stirrer to form sodium methoxide solution in the case of base/alkali catalyst. Meanwhile, the oil was warmed by placing the round-bottomed flask in the water bath maintained at the selected temperature mentioned above. The sodium methoxide solution or acid catalyst solution was added into the oil for vigorous mixing by means of a mechanical stirrer fixed into the flask. The required temperature was maintained throughout the reaction time and the reacted mixture was poured into the separating funnel. The mixture was allowed to separate and settle overnight by gravity settling into a clear, golden liquid biodiesel on the top with the light brown glycerol at the bottom. The next day, the glycerol was drained off from the separating funnel, leaving the biodiesel /ester at the top. The raw bio-diesel was collected and water-washed to bring down the pH of biodiesel to 7. This pure biodiesel gives the ester yield measured on weight basis and the important fuel and chemical properties were determined and compared with the properties of raw oil and BIS standards. The emulsion that comes out during washing of ester was also collected and weighed.

After having optimized the concentration of methanol, NaOH and the time required for trans-esterification of Jatropha oil, experimental studies on large-scale production of biodiesel were carried out in the Chhattisgarh Bio Fuel Development Authority, VIP Road, Raipur biodiesel pilot plant. The best treatment with higher yield of ester/biodiesel was analyzed and selected for biodiesel production in the pilot plant among the various treatments. The pilot plant consists of a biodiesel reactor with heating and agitating devices, catalyst mixing tank, glycerol settling tanks and bio-diesel washing tank. The production capacity of the bio-diesel pilot plant is 3 tons per day. The pure ester yield was determined after settling the glycerol and washing the ester. The fuel properties of Jatropha curcus oil help in assessment of its suitability as fuel in diesel engines. The chemical properties of raw oil give an idea of the possibility of bio-diesel production and its effect on bio-diesel yield.

The fuel properties such as kinematic viscosity and specific gravity and chemical properties such as free fatty acid and acid value were determined for raw oil and trans-esterified Jatropha oil according to standard test methods.

A statistical tool, completely randomized design with single factor analysis, was used to predict optimal conditions for maximum bio-diesel production from alkali-catalysed trans-esterification of Jatropha curcus oil. The parameters considered to find out higher bio-diesel production were percentage of methanol, catalyst amount, reaction time and reaction temperature. The significance was tested using least square difference (LSD) both at 5 and 1% levels. The sample taken for the study was 200 grams and the data were converted to 100 grams basis for analysis. The experiment was repeated three times and average value of methyl ester yield was calculated.

3. Properties of bio-diesel & diesel: A Comparison

The ideal diesel fuel molecules are saturated non-branched hydrocarbon molecules with carbon number ranging between 12 to 18 whereas vegetable oil molecules are triglycerides generally with no branched chains of different lengths and different degrees of saturation. It may be noticed that vegetable oils contains substantial amount of oxygen in their molecular structure. Fuel properties for the combustion analysis of vegetable oil can be grouped conveniently into physical, chemical, thermal properties. Physical properties include viscosity, density, cloud point, pour point, flash point, boiling range, freezing point and refractive index. Chemical properties comprise chemical structure, acid value, saponification value, iodine value, peroxide value, hydroxyl value, acetyl value, and overall heating value, ash, and sulphur contents, sulphur and copper corrosions, water and sediment residues, oxidation resistance, ignitability and thermal degradation products. The thermal properties are distillation temperature, thermal degradation point, carbon residue, specific heating content, and thermal conductivity. Tab. 1 [3] shows the comparison of various properties of bio-diesel prepared from jatropha seeds and diesel.

4. Results & Discussion

The performance test was conducted on single cylinder vertical high speed Kirloskar diesel engine at National Institute of Technolgy, Raipur, CG.. The secifications of the engine are given as below:

- rated horse power 10 BHP,
- speed 1500 rpm,
- Compression Ratio 16.5:1.

Tab. 1. Comparison of Properties of Bio Diesel and Standard Specification of Diesel

Standard Specification	Specification of Jatropha oil (Bio Diesel)	Standard Specification of Diesel
Specific Gravity	0.9186	0.82-0.84
Flash Point	110^0C	50^oC
Carbon Residue	0.64	0.15 or less
Cetane Value	57.0	47.0 or above
Distillation Point	295^0C	350^0C
Kinematics viscosity	5.23 cs	2.7 cs
Sulphur (%)	0.014%	1.2% or less
Calorific Value	9.470 kcal/kg	10.170 kcal/kg
Pour Point	8^oC	10^oC
Carbon, wt%	77	87
Hydrogen, wt%	12	13
Boiling Point	$182\text{-}338^oC$	$188\text{-}343^oC$
Stoichometric Air/Fuel Ratio	13.8	15
Colour	4.0	4.0 or less
Toxicity	Essentially non-toxic	Highly toxic
Oxygen	Up to 11% free O_2	Very Low
Aromatics	No aromatic compound	18-22%
Spill hazard	None	High
Renewablable Supply	Renewable Fuel	Non-Renewable
Production Process	Chemical Reaction	Reaction + Fraction
Alternate Fuel	Yes	No

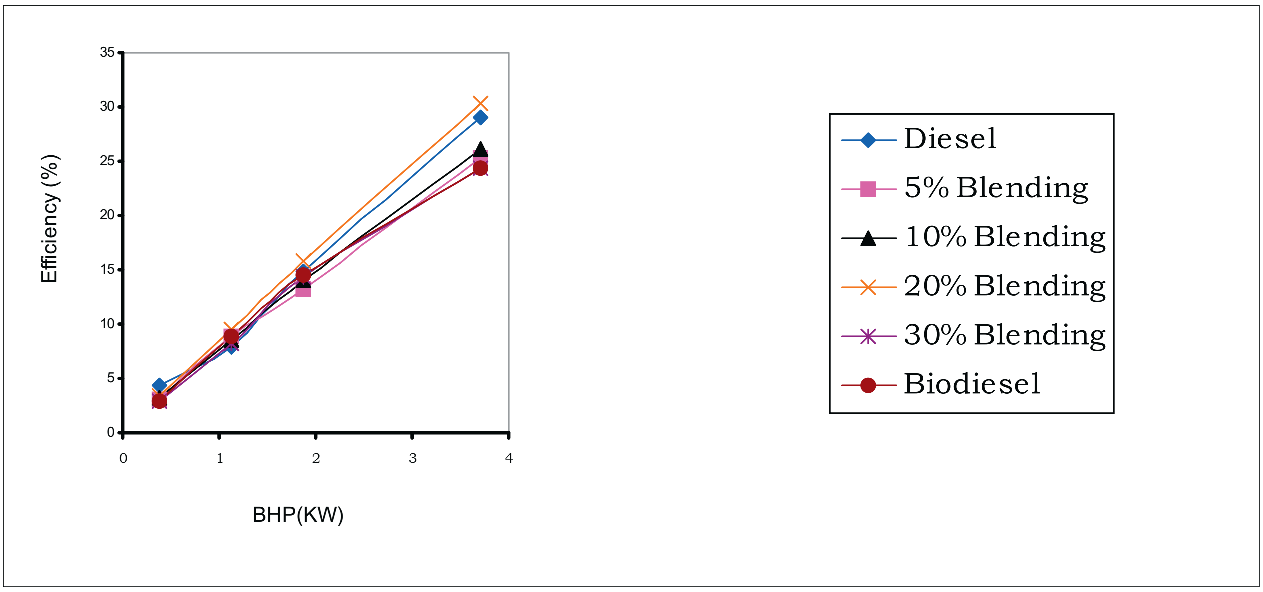

Fig. 1. Variation of Efficiency with BHP of Bio-diesel, Petro-diesel, blending

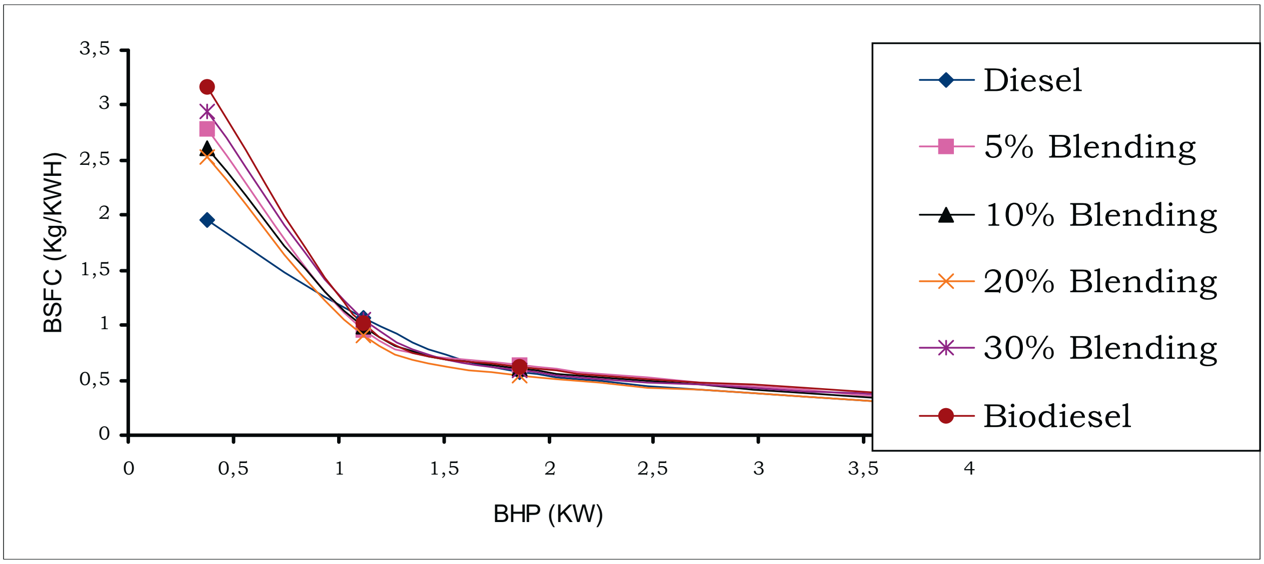

Fig. 2. Variation of BSFC with BHP of Bio-diesel, Petro-diesel, blending

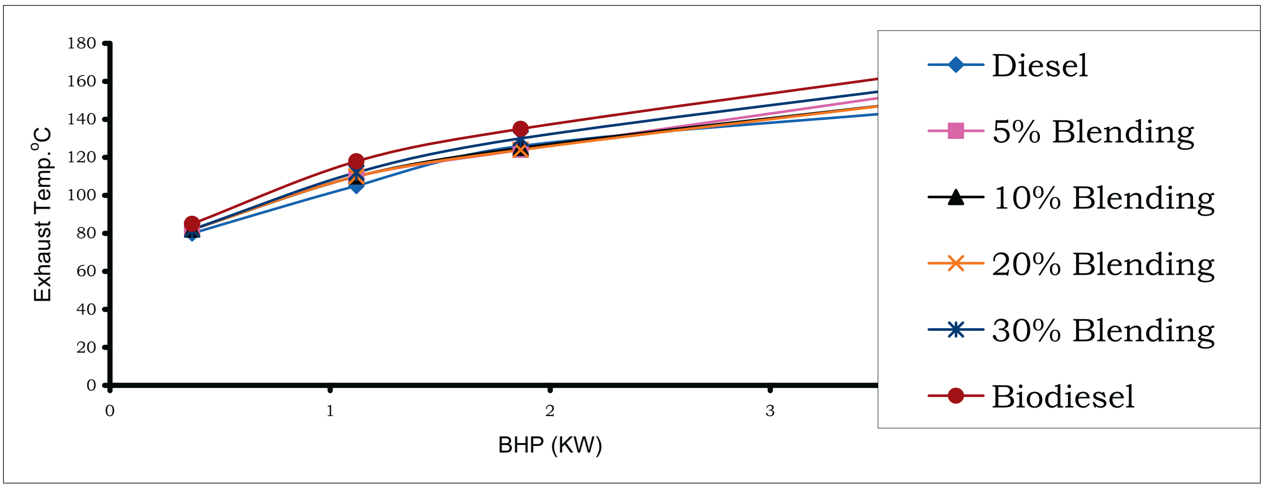

Fig. 3. Variation of Exhaust gas temperature with BHP of Bio-diesel, Petro-diesel, blending

The performance parameter such as fuel consumption and exhaust temperature were measured by running the engine using petro diesel. The same experimental procedure was repeated with bio-diesel and different blends of bio-diesel (5%, 10%, 20%, 30%). The variations of thermal efficiency(η) with brake horse power (BHP) are shown in Fig. 1. Owing to poor mixture formation, as a result of the low voltality and slightly higher viscosity, the η is found lower with bio-diesel (jatropha) as compared to diesel. The variations of brake specific fuel consumption (BSFC) with BHP are shown in Fig. 2. It is observed that at maximum load, the BSFC of bio-diesel is higher as compared to diesel due to less calorific value of bio-diesel. The variations of exhaust gas temperature (Te) with BHP are shown in Fig. 3. Te is higher with bio-diesel for all proportions of bio-diesel as compared to diesel due to the availability of atoms of oxygen in bio-diesel.

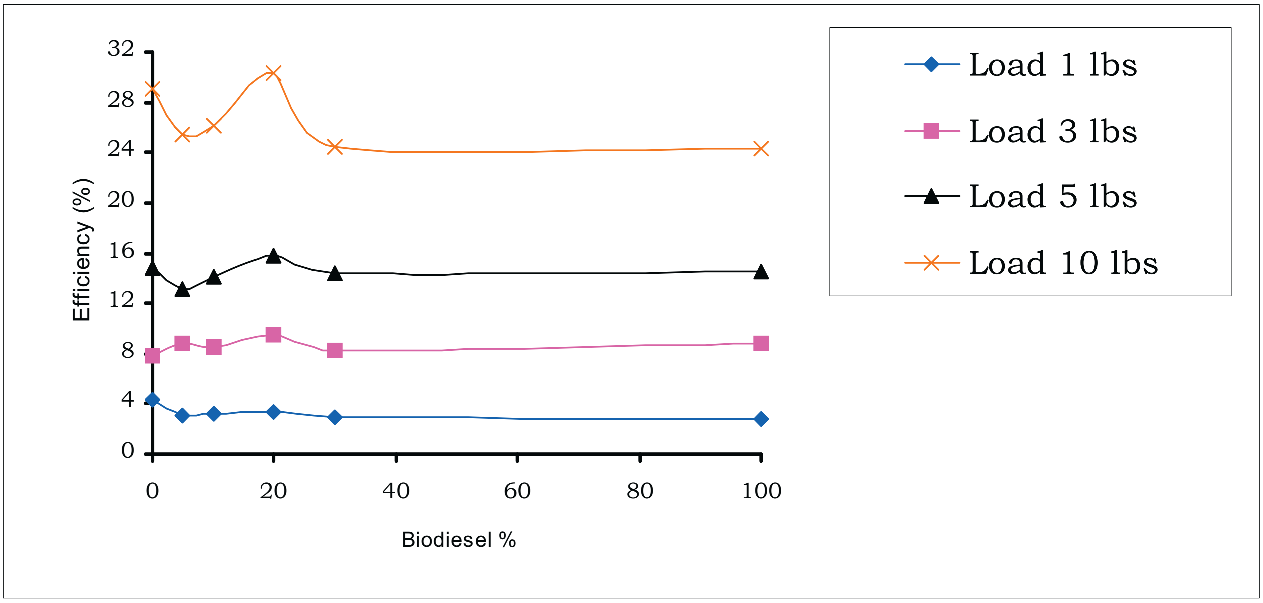

Fig. 4. Variation of Efficiency with percentage of Bio-diesel in different load

Fig. 4 shows the variations of bio-diesel content on efficiency of engine. It is observed that as the load on the engine increases, the efficiency of engine also increases for different composition of bio-diesel and conventional diesel. It is found that 20% blend of bio-diesel gave the maximum efficiency for the different loads.

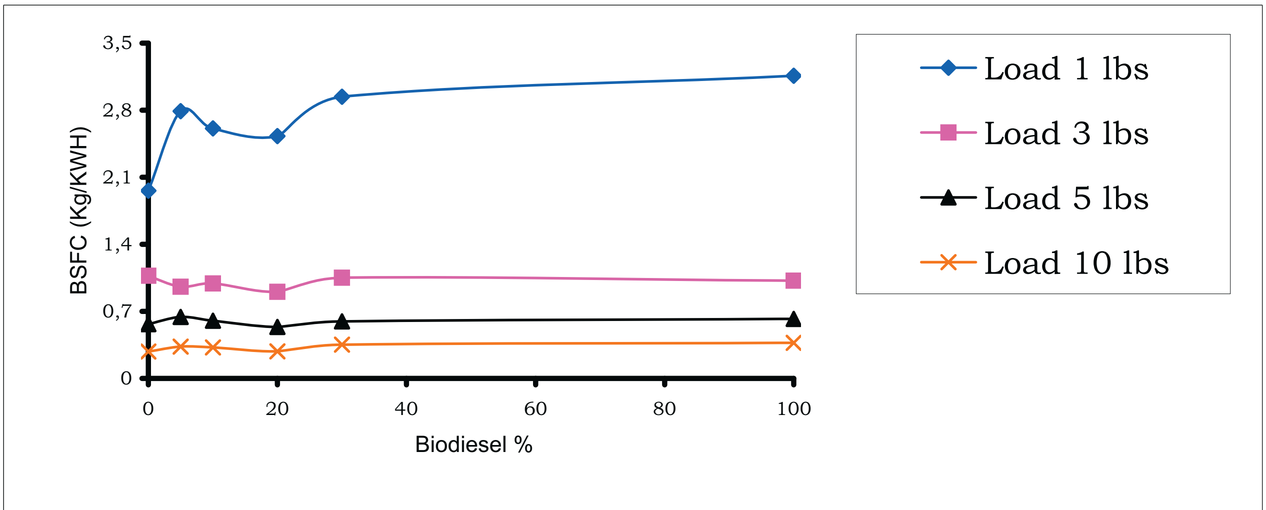

Fig. 5. Variation of BSFC with percentage of bio-diesel in different load

Fig. 5 shows the variation of bio-diesel content on BSFC of the engine. It is observed that as the load increases on the engine, BSFC also increases. It is also observed that 20% blend of bio-diesel gave the maximum BSFC for the different loads.

Fig. 6 shows the variation of bio-diesel content on exhaust gas temperature (Te). It is observed that as the load increases on the engine, Te also increases. It is also observed that minimum Te has been observed for the 20% blend of bio-diesel for the different loads.

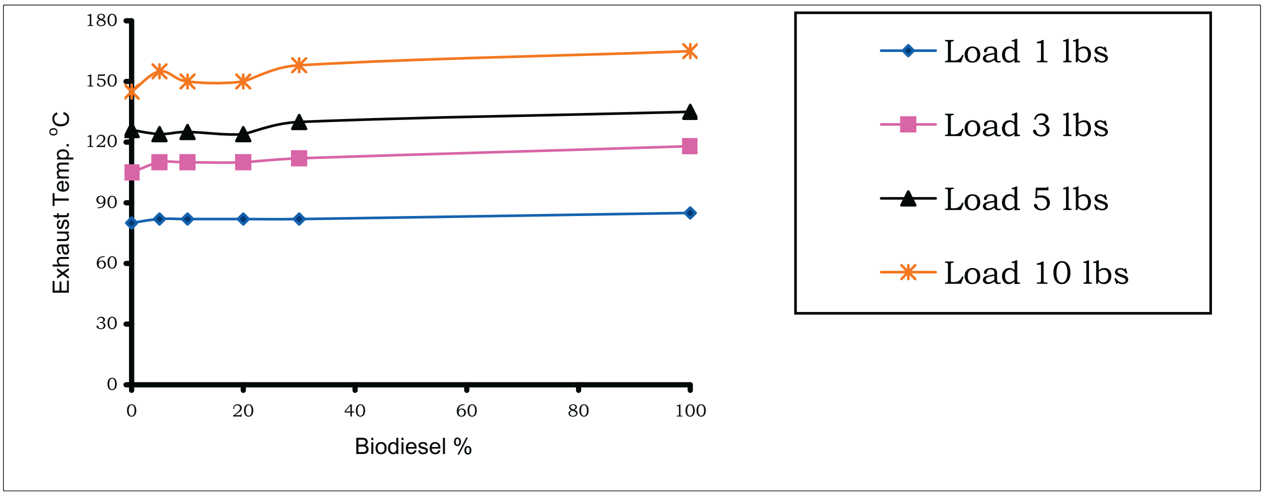

Fig. 6. Variation of Exhaust gas temperature with percentage of bio-diesel in different load

Results obtained in the laboratory are found in good agreement with the results of bio-diesel prepared from linseed [4].

5. Conclusion

Alternate fuels for diesel engines have become increasingly important due to decreasing petroleum reserves and the environmental consequences of exhaust gases from petro-fuel. Thus bio-diesel can be adopted as an alternative fuel for the existing diesel without any major modification in the system hardware. The esterification process can reduce the viscosity of vegetable oil. Therefore, this process should be properly controlled to get the desirable properties of bio-diesel. The different tests for characterization of bio-diesel demonstrated that almost all the important properties of bio-diesel are in close agreement with the diesel oil making it a potential candidate for the application in diesel engine for partial replacement of diesel fuel.

It has been observed that 20% blend of bio-diesel gives better performance on diesel engine without any modification in the engine.

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