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EXPERIMENTAL INVESTIGATIONS OF PERFORMANCE AND EMISSION CHARACTERISTICS OF A CI ENGINE FUELED WITH SOYBEAN BIO DIESEL

N. Ravi Kumar, Rajesh Guntur, Shamali S.V, Y.M.C. Sekhar

Department of Mechanical Engineering, MVGRCE, Vizianagaram, (A.P.)

E-mail of Corresponding Author: stanlyrajesh@gmail.com

ABSTRACT

The use of alternate fuels in compression ignition (CI) engines is increasing day by day in the form of blends with diesel. Biodiesel is a non–toxic, biodegradable and renewable alternative fuel that can be used with little or no engine modifications. The objective of this study was to investigate the effect of the biodiesel produced from soybean oil on single cylinder high speed diesel engine. Both performance and emission characteristics were studied in the range of no load to full load. The experimental results have showed that the brake thermal efficiency and mechanical efficiency of soybean biodiesel are better than diesel. Smoke is reduced by 19 % at part loads and NO_x emissions are marginally increases at all loads with biodiesel operation.

Keywords: Bio fuels, high speed diesel engine, bsfc, emissions, soybean methyl esters

INTRODUCTION

Depletion of fossil fuel resources increasing with each passing day and raising the demand of fuels. Concurrently, increasing stringent regulations, pose a challenge to science and technology. Global Warming and Environmental pollution are also a serious threats which have been caused by excessive use of fossil fuels for transportation. Now a day's biodiesel is the most promising source of renewable energy with high potential to replace petroleum-derived diesel fuel, because of similarity in chemical properties. Biodiesel, as an alternative fuel of diesel, is described as fatty acid methyl or ethyl esters from vegetable oils or animal fats. Biodiesel is renewable, oxygenated and eco-friendly [1]. Vegetable oils are obtained largely from grains of different plant species. There are two methods of oil extraction. One is by physical process (pressing) and other is by chemical (solvent). Soybean is a very flexible grain that gives the products widely used in agro-chemical industry and food industry. Besides it is a raw material for extraction of oil for bio fuel. About 20% of oil is available in soybean grain. Countries like United States, Brazil, Argentina, China and India are producing Soybean large in content. [2]. Grau et al. [3] stated that straight vegetable oil can be used directly in diesel engines with minor modifications. It is proposed a small-scale production system for self supply in agricultural machinery. Plenty of literature is available related to research of engine performances and its emissions when using biodiesel. Misra & Murthy [4] reported the main advantages of vegetable oils are its life cycle, as it is a closed cycle. Crops take CO_2 via photosynthesis from the atmosphere. Oil is extracted from these crops which can be used as a fuel directly or after the pertinent transformations. As a result of transformation, CO_2 will be produced and the same can be absorbed by the plants. The main disadvantages of vegetable oils, compared to diesel fuel, are higher viscosity, lower volatility, and the reactivity of unsaturated hydrocarbon chains. The problems meet in long term engine use.

Basha et al. [5] presented a review paper on biodiesel production, combustion, emissions and performance. The study reported that short-term engine tests were very promising when using vegetable oils as fuels, but the long-term test results showed higher carbon built up, lubricating oil contamination and engine failure. It was reported that the combustion characteristics of biodiesel are similar as diesel. The engine power output was found to be equivalent to that of diesel fuel.

Van Dam et al. [6] presented the potential and economic feasibility of large-scale bio energy production from soybeans for national and international markets. Jinlin Xue.et.al [1] reviewed the effect of biodiesel on engine performance and emissions. He reported that with biodiesel (especially with pure biodiesel), engine power will drop due to the loss of heating value of biodiesel. But Some other authors found that the power loss was lower than expected (the loss of heating value of biodiesel compared to diesel) because of power recovery. Yucesu HS and Cumali I [7] found that the torque and power reduced by 3–6% for pure cotton seeds biodiesel compared to diesel, and they claimed that the heating value of biodiesel was less 5% than that of diesel. But they contributed to the difficulties in fuel atomization instead of the loss of heating value.

Lin et al. [8] found that the maximum and minimum differences in engine power and torque at full load between petroleum diesel and 8 kinds of vegetable oil methyl ester fuels were only 1.49% and −0.64%, 1.39% and −1.25%, respectively, due to higher viscosity, higher BSFC (brake specific fuel consumption), higher oxygen content and higher combustion rate of biodiesel. M. Canakci and J. H. Van Gerpen [9] compared the engine performance and emissions for petroleum biodiesel and soybean biodiesel. They found that the oxides of nitrogen increased by 13% for soybean oil methyl ester. The conversion of the biodiesel fuel's energy to work was equal to that from diesel fuel. Most of researches agreed that the fuel consumption of an engine fueled with biodiesel becomes higher because it is needed to compensate the loss of heating value of biodiesel. Armas et al. [10] found that the BSFC of B100 biodiesel, which the LHV (low heating value) was 12.9% lower than that of BP15,had increased approximately 12% compared to the BP15 on a 2.5 L,DI and TU, common-rail diesel engine operated at the speed of 2400rpm and torque64Nm. Generally With increase in load, the brake specific fuel consumption of biodiesel decreases due to increase in the brake power. Gumus M and Kasifoglu S [11] showed that the BSEC initially decreased with increasing of engine load until it reached a minimum value and then increased slightly with further increasing engine load for all kind of fuels.

Many literatures showed that NOx emissions increase with the increase in content of biodiesel. Lujan et al. [12] tested on a HSDI, 4-cylinder, 1.6 L, TU diesel engine fueled by biodiesel and its blends B30, B50 and B100. The authors observed that the increase in NOx emissions for B30, B50 and B100 could be scored at 20.6%, 25.9% and 44.8%, respectively. Aydin H and Bayindir H [13] investigated engine performances and emissions of CSOME and its blends (B5, B20, B50 and B75) on a single-cylinder DI and AC diesel engine. It could be observed that the increasing content of biodiesel in the blends resulted in the reduced NOx emissions, and all blends except for B5 decreased the NOx emissions in the study.

Sahoo et al. [14] compared three kinds of biodiesels from jatropha, karanja and polanga oil and their blends (B20, B50 and B100) and found that the biodiesels from karanja and polanga oil and their blends had the trend of the NOx increase with the increased content of biodiesel, but there was variation for jatropha oil biodiesel because the NOx emissions value for JB100 was lower than that of JB20. According to most of literatures it is common trend that CO emissions reduce when diesel is replaced by pure biodiesel. Krahl et al. [15] obtained about 50% reduction in CO emissions for biodiesel from rapeseed oil compared to low and ultra low sulphur diesel. Banapurmatha et al. [16] compared the CO emissions for JOME, SOME and HOME with that of diesel on a single-cylinder, 4-stroke, DI, WC, and CI engine at a rated speed of 1500 rpm. They reported that significant increase in CO emissions for pure biodiesel compared with diesel. Puhan et al. [17] reported that the HC emissions reduced average around 63% for biodiesel compared with diesel.

M. Mani.et al. [18] studies the performance, combustion and emission characteristics of diesel engine using waste plastic oil. Their experimental results showed that a stable performance with brake thermal efficiency similar to that of diesel. Carbon dioxide and unburned hydrocarbon were marginally higher than that of the diesel baseline. The toxic gas carbon monoxide emission of waste plastic oil was higher than diesel. Smoke reduced by about 40% to 50% in waste plastic oil at all loads.

The majority of the works reported in literature studied biodiesel produced from feed stocks with relatively low free fatty acids. The biodiesel was generally prepared using alkaline–catalyzed processes that were similar to those used for high–quality soybean oil. In the present work biodiesel is produced from raw soybean oil by Transesterification and tested on single cylinder slow speed diesel engine for finding the performance and emission characteristics at different loads.

PREPARATION OF SOYBEAN OIL BIODIESEL

The use of vegetable oils in place of diesel fuel in conventional diesel engines requires certain modification of their properties like viscosity and density. Transesterification is the general term used to describe the important class of organic reactions, where an ester is transformed into another ester through interchange of alkyl groups and is also called alcoholysis. Transesterification is an equilibrium reaction and the transformation occurs by mixing the reactants. In the transesterification of vegetable oils, a triglyceride reacts with an alcohol in the presence of a strong acid or base, producing a mixture of fatty acid alkyl esters and glycerol. In the base-catalyzed process, the transesterification of vegetable oils proceeds faster than the acid-catalyzed reaction. The biodiesel is obtained from soybean oil in the following steps

1. The soybean oil is filtered using surgical cotton to eliminate the water and particulate matter.
2. The oil is heated to 100^{o}C temperature and maintained for 15 minutes. It is allowed to settle for one day for removal of water.
3. 6.5 grams of sodium hydroxide (NaOH) is added to 0.12 liters of methanol and stirred thoroughly to produce sodium methoxide.
4. Half of the prepared sodium methoxide is poured into the unheated mixture and the mixture is stirred for five minutes. This will neutralize the sulfuric acid.
5. The mixture is heated to 55^{o}C and the whole reaction is maintained.

6. After heating for one hours the oil should be poured into decanter
7. Glycerin is removed and it is ready for water wash
8. water wash should be done with Phosphoric acid

PROPERTIES OF THE BIO-DIESEL

The property of soybean oil biodiesel was found in the fuels laboratory. The results obtained are shown in Table 1.

EXPERIMENTAL SETUP

In the present work a four stroke single cylinder, water cooled, direct injection, vertical diesel engine, was tested for soybean oil biodiesel operation. The specifications of the engine are given in table 2. A Schematic of the experimental arrangement is shown in Figure 2. Air flow was determined using air box method by measuring the pressure drop across a sharp edge orifice of the air surge chamber with the help of a manometer. The diesel flow was measured by noting the time of fixed volume of diesel consumed by the engine. The speed of the engine was measured by help of digital tachometer. The loading is applied on the engine using rope brake dynamometer. The exhaust gas constituents HC, CO, CO_2, NO_x, O_2 are measured using AVL DiGas 444 gas analyzer and smoke opacity was measured using AVL 437C smoke meter.

UNCERTAINTY ANALYSIS

Errors will creep into all experiments regardless of the care which is exerted. Errors and uncertainties in the experiments can arise from instrument selection, condition, calibration, environment, observation, reading and test planning. Uncertainty analysis is needed to prove the accuracy of the experiments [19]. The percentage uncertainties of various parameters like brake power and brake thermal efficiency were calculated using the percentage uncertainties of various instruments given in Table 3. An uncertainly analysis was performed using Eq. (1).

$$Y = \sqrt{X_1^2 + X_2^2 + X_3^2 + X_4^2 + X_5^2 + X_6^2 + X_7^2} \quad (1)$$

$$Y = \sqrt{(0.2)^2 + (1)^2 + (0.15)^2 + (0.2)^2 + (1)^2 + (0.2)^2 + (1)^2} \quad (2)$$

Total percentage of uncertainty of this experiment

Y= $\pm$1.77%

RESULTS AND DISCUSSION

In this section we investigate the performance and emission characteristics of a high speed diesel engine at various loads from no load to full load fuelled with soybean oil biodiesel and compared with standard diesel.

Specific Fuel Consumption

Figure 3 shows the variation of specific fuel consumption with brake power. It is observed that with increase in brake power the specific fuel consumption is decreases for both diesel and soybean oil. Further it is noticed that compared with diesel the specific fuel consumption of the engine increases when soybean oil is used. At part loads the increase in specific fuel consumption is 5.4% but as the load increases this value decreases and reached to 0.37% at full load. Therefore the specific fuel consumption of the engine at full load (maximum power) is nearly same when it is operated with diesel and soybean biodiesel.

Mechanical Efficiency

The variation of mechanical efficiency with brake power is shown in figure 4. It can be observed from the figure that at rated power the mechanical efficiency is 62.2% for Diesel and 62.7% for soybean biodiesel. It is clear that the mechanical efficiency of soybean oil is very close to diesel from no load to full load.

Brake thermal Efficiency

Figure 5 shows the variation of brake thermal efficiency with brake power. It is found that with increase in brake power the brake thermal efficiency also increases. It is observed that at any load condition the brake thermal efficiency of soybean oil is greater than diesel. At part load conditions the percentage increase in brake thermal efficiency is 7% but with increase in brake power this value also increases and reaches 13% at full load.

Oxides of Nitrogen

Oxides of nitrogen are the important emission in diesel engines. The oxides of nitrogen in the emissions contain nitric oxide (NO) and nitrogen dioxide (NO_2). The formation of NO_x is highly dependent on in-cylinder temperature and oxygen concentration. Figure 6 shows the variation of oxides of nitrogen with brake power. It can be observed that NO_x emission increases in the soybean bio diesel operation. At part load conditions the increase in NO_x emissions is 40% whereas it reduces as the load increases and reached the value of 12.7% at full load.

Smoke

Smoke is nothing but solid soot particles suspended in exhaust gas. Figure 7 shows the variation of smoke with brake power. Smoke opacity varies from 9.8HSU to 80.3 HSU for diesel operation and from 3.2HSU to 79.1 HSU for soybean biodiesel. It can be noticed that the smoke level for soybean biodiesel is lower than diesel at part load and full loads. The reason for the reduced smoke is the availability of premixed and homogeneous charge inside the engine well before the commencement of combustion. Higher combustion temperature, extended duration of combustion and rapid flame propagation are the other reasons for reduced smoke

Carbon Monoxide

Generally the CO emissions in diesel engines are low because they operate with excessive air. CO emission is toxic and must be controlled. It is an intermediate product in the combustion of a hydrocarbon fuel, so its emission results from incomplete combustion. The variation of carbon monoxide with load is shown in figure 8. The concentration of CO emissions varies from 0.02% to 0.05% for diesel and for soybean bio diesel it is in between 0.03-0.04%. the results showed that from no load to 60% load the CO emissions are low with soybean bio diesel operation, but at full load this will slightly increase than diesel. The sudden increase in CO emission at higher loads is due to higher fuel consumption.

CONCLUSIONS

The following conclusions are drawn from the experimentation conducted on single cylinder high speed diesel engine operated with diesel and soybean biodiesel

- Soybean Biodiesel showed high brake specific fuel consumption than the diesel for same power developed due to its lower calorific value
- Increase in Brake thermal efficiency was observed when the engine fueled with soybean biodiesel.
- Mechanical efficiency with soybean Biodiesel is higher at all the loads when compared to Diesel fuel.
- NOx emissions is higher for soybean biodiesel by 12.7% at full load due to more availability of oxygen
- Smoke reduced by 19% at part loads and 2% at rated power in soybean biodiesel compared to diesel operation
- CO emissions are increased with soybean biodiesel compared to diesel operation

Nomenclature

CO carbon monoxide
HC hydro carbon
NO_x oxides of nitrogen
CO_2 carbon dioxide

HSU Hatridge smoke unit
BTDC before top dead centre
Y total percentages of uncertainty
X_1 uncertainty of NOx
X_2 uncertainty of unburned hydro carbon
X_3 uncertainty of carbon monoxide
X_4 uncertainty of smoke opacity
X_5 uncertainty of brake power
X_6 uncertainty of fuel consumption
X_7 uncertainty of brake thermal efficiency

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REFERENCES

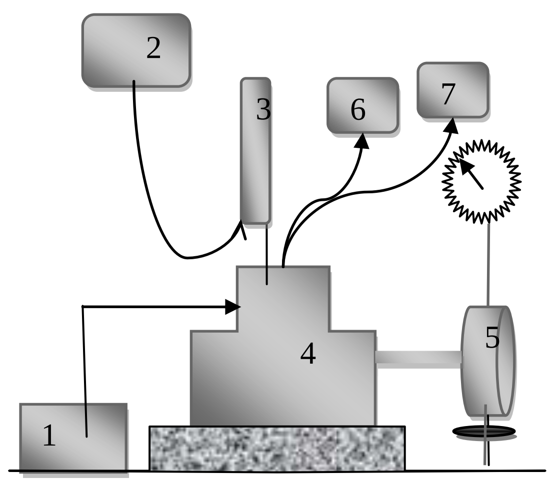
1. Jinlin Xue, Tony E. Grift , Alan C. Hansen, “Effect of biodiesel on engine performances and emissions”, renewable and sustainable energy reviews, 15 (2011) 1098–1116.
2. Roberto Guimarães Pereira,Oscar Edwin Piamba Tulcan,Valdir de Jesus Lameira, Dalni Malta do Espirito Santo Filho,and Ednilton Tavares de Andrade, **“**Use of Soybean Oil in Energy Generation”, Recent Trends for Enhancing the Diversity and Quality of Soybean Products, pp 301-320.
3. Grau, B.; Bernat, E.; Antoni, R.; Jordi-Roger, R. & Rita, P., “Small-Scale Production of Straight Vegetable Oil from Rapeseed and its use as Biofuel in the Spanish Territory”, Energy Policy, Vol. 38, Issue 1, (January 2010), pp. 189-196.
4. Misra, R. & Murthy M., “Straight Vegetable Oils usage in a Compression Ignition Engine - A Review”. Renewable and Sustainable Energy Reviews, Vol. 14, Issue 9, (December 2010), pp. 3005-3013.
5. Basha, S.; Gopal, K. & Jebaraj, S., “A Review on Biodiesel Production, Combustion, Emissions and Performance”, Renewable and Sustainable Energy Reviews, Vol. 13, Issues 6-7, (August-September 2009), pp. 1628-1634.
6. Van Dam, J.; Faaij, A.; Hilbert, J.; Petruzzi, H. & Turkenburg, W. (2009). Large-Scale Bioenergy Production from Soybeans and Switch grass in Argentina: Part A: Potential and Economic Feasibility for National and International Markets. Renewable and Sustainable Energy Reviews, Vol. 13, Issue 8, (October 2009), pp. 1710-1733.
7. Yucesu HS, Cumali I˙, “Effect of cotton seed oil methyl ester on the performance and exhaust emission of a diesel engine”, Energy Source Part A 2006; 28:389–98.
8. Lin B-F, Huang J-H, Huang D-Y., “Experimental study of the effects of vegetable oil methyl ester on DI diesel engine performance characteristics and pollutant emissions”, Fuel 2009; Vol 88:1779–85.
9. M. Canakci, J. H. Van Gerpen, Comparison of engine performance and emissions for petroleum diesel fuel, yellow grease biodiesel, and soybean oil bio biodiesel, American Society of Agricultural Engineers,2003, Vol. 46(4): 937–944.
10. Armas O, Yehliu K, Boehman AL., “Effect of alternative fuels on exhaust emissions during diesel engine operation with matched combustion phasing”, Fuel, 2010, 89:438–56.
11. Gumus M, Kasifoglu S., “Performance and emission evaluation of a compression ignition engine using a biodiesel (apricot seed kernel oil methyl ester) and its blends

with diesel fuel", Biomass Bio energy 2010; 34:134–139.
12. Lujan JM, Bermudez V, Tormos B, Pla B., "Comparative analysis of a DI diesel engine fuelled with biodiesel blends during the European MVEG-A cycle: Performance and emissions (II)", Biomass Bio energy 2009; 33:948–56.
13. Aydin H, Bayindir H., "Performance and emission analysis of cottonseed oil methyl ester in a diesel engine", Renew Energy 2010; 35:588–92.
14. Sahoo PK, Das LM, Babu MKG, Arora P, Singh VP, Kumar NR, "Comparative evaluation of performance and emission characteristics of jatropha, karanja and polanga based biodiesel as fuel in a tractor engine", Fuel 2009;88:1698–707.
15. Krahl J, Munack A, Schroder O, Stein H, Bunger J., "Influence of biodiesel and different designed diesel fuels on the exhaust gas emissions and health effects", SAE paper 2003, 2003-01-3199.
16. Banapurmatha NR, Tewaria PG, Hosmath RS, "Performance and emission characteristics of a DI compression ignition engine operated on Honge, Jatropha and sesame oil methyl esters", Renew Energy 2008;33:1982–88.
17. Puhan S, Vedaraman N, Sankaranarayanan G, Bharat Ram BV., "Performance and emission study of Mahua oil (Madhuca indica oil) ethyl ester in a 4-stroke natural aspirated direct injection diesel engine", Renewable Energy 2005; 30:1269–78.
18. M. Mani , C. Subash, G. Nagarajan, "Performance, emission and combustion characteristics of a DI diesel engine using waste plastic oil", Applied Thermal Engineering 29 (2009) 2738–2744.
19. Holman JP. Experimental techniques. Tata McGraw Hill Publications; 2003.

(a) Raw soybean oil **(b)after adding methoxide**

(c) Decantation for Glycerin removal **(d) water washing**

Figure: 1 Transesterification process of soybean methyl ester preparation



1. Air box 2. Fuel Tank 3. Burette 4.Engine 5. Dynamometer 6.Smoke Meter 7.Gas Analyzer

Fig 2 Experimental setup of the test engine

Table.1 Comparison of properties between Diesel and soybean oil biodiesel

S.No	Property	Diesel	soybean methyl ester
1	Density at 30°C kg/m^3	830	885
2	Net Calorific Value, kJ/Kg	42500	37400
3	Viscosity at 33 °C, cst	2.75	4.5
4	Cetane Number	42	45
5	Flash Point, °C	50	155
6	Pour Point, °C	-12	-6

Table 2. Engine Specifications

Make	Kirloskar
type	Four stroke, water cooled
Bore	80mm
stroke	110mm
No of cylinders	1
bhp	5
Compression ratio	16.5:1
Rated speed	1500rpm
Injection timing	23^0BTDC
Injection pressure	200bar

Table: 3 List of instruments and its range, accuracy and percentage uncertainties.

S. No	Instrument	range	accuracy	% uncertainty
1	AVL DiGas 444 analyzer NOx	0-5000 ppm vol	<500ppm Vol:±50 ppm vol >500ppm vol: : ±10 ppm value	± 0.2
2	HC	0-20000 ppm vol	<200 ppm: ±10 ppm val >200ppm vol:10 ppm vol	± 0.2
3	CO	0-10% vol	<0.6%vol: +0.03%vol >0.6%vol: +5% of Ind.val	± 0.2
4	CO_2	0-20% vol	<10% vol: ± 0.5%vol > 10% vol: ± 5% vol	± 0.15
5	Smoke opacity	0-100%	± 1% of full scale	± 1
6	tachometer	0-10000 rpm	± 10rpm	± 0.1
7	Stop watch	----	± 0.2s	± 0.2
8	Mano meter	----	± 1 mm	± 1
9	Load indicator	0-100kg	±0.1kg	± 0.2
10	Burette for fuel measurement	----	± 0.1cc	± 1

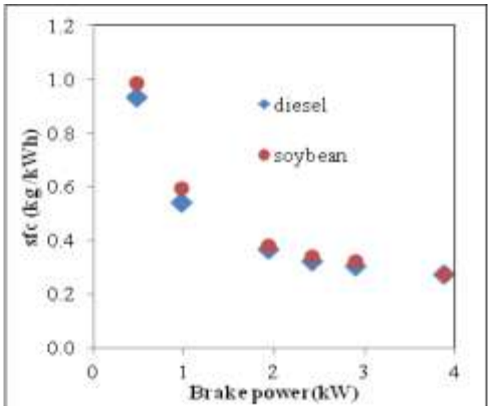


Figure: 3 Variation of specific fuel consumption with brake power

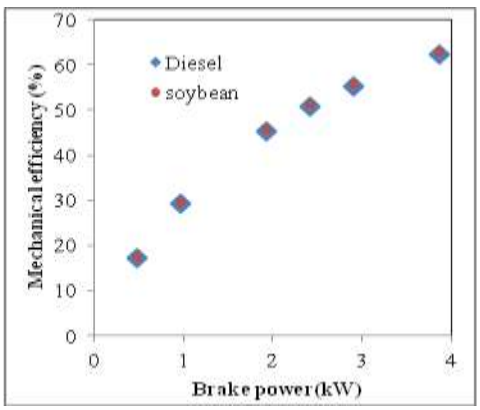


Figure: 4 Variation of mechanical efficiency with brake power

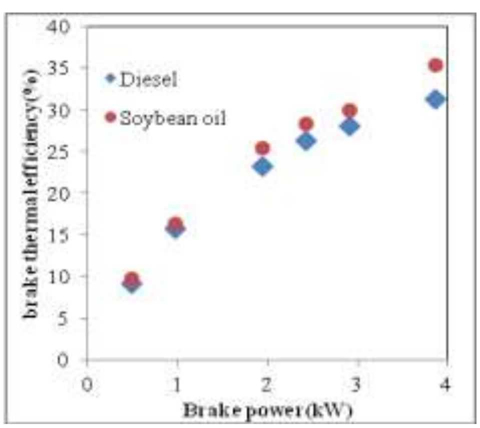


Figure: 5 Variation of brake thermal efficiency with brake power

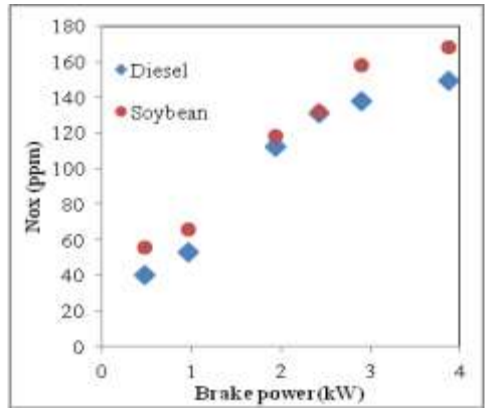


Figure: 6 Variation of oxides of nitrogen with brake power

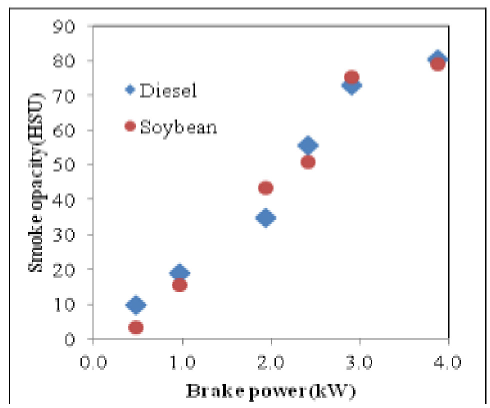


Figure: 7 Variation of Smoke Opacity with Brake power

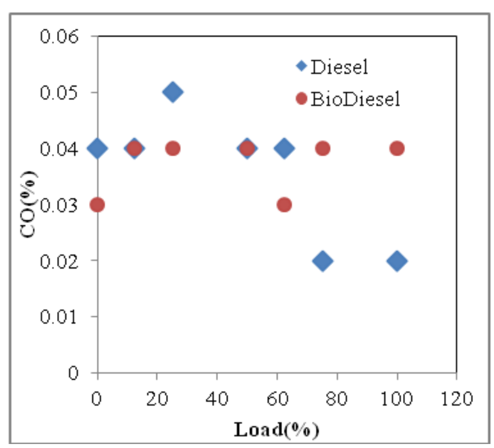


Figure: 8 Variation of carbon monoxide with load