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Research Article

An Experimental Investigation of Jatropha Biodiesel Blends in a Multi Cylinder CI Engine: Performance and Emissions Study

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Abstract

There is tremendous increase in transportation activities in recent times. Petroleum fuels are the key energy source in India and preferred as automotive fuel. Their use has been increasing continuously from 3.5 MMT (Million Metric Tons) in the year 1950-51 to 84.3 MMT in 1997-98 and about 113 MMT in 2001 and it were about 148 MMT in 2011-12. Petroleum based fuels are obtained from limited reserves which are highly intense in certain regions of the world. Therefore, those countries that do not have these resources and facing a foreign exchange crisis are looking for alternative fuels, which can be produced from materials available inside the country. Biodiesel is considered as clean fuel since it has almost no sulphur, no aromatics and has about 10 % built in oxygen, which helps it to burn fully. In present paper the engine performance and exhaust emissions of jatropha oil biodiesel blends, were investigated on a 39 kW multi cylinder engine, in B10 to B30 percent blends and compared with the petroleum diesel fuel. The experimental results show that the engine power and torque of the mixture of oil–diesel fuel are close to the values obtained from diesel fuel and the amounts of smoke, CO and HC exhaust emissions are lower than those of diesel fuel, except slight increase of NOx emissions at higher loads.

Keywords*: Diesel Engine, Performance testing, Emissions, Smoke, jatropha, biodiesel*

1. Introduction

The world is presently facing the twin problems of fossil fuel depletion and severe environmental degradation. Haphazard extraction and lavish consumption of fossil fuels resulted in reduction of underground carbon resources. The search for alternative fuels, which promise a melodious correlation with sustainable development, energy preservation, efficiency and environmental protection, has become highly prominent in the present context. In the last decade, several researchers have been examined that vegetable oils may be proved as one such alternative fuel and their potential. Vegetable oils are renewable and eco-friendly to the environment, and they are free of sulphur content in them. This makes vegetable fuel studies become current issue among the various popular investigations. Bio-diesel have many advantages over petroleum diesel fuel; produce less smoke and particulates, have high cetane number, produce lower carbon monoxide and hydrocarbon emissions, renewable, biodegradable and non-toxic. In India, with abundance of forest resources, there are a number of other non-edible tree borne oilseeds with an estimated annual production of more than 20 million tones, which have large potential for making biodiesel to supplement other conventional sources. Biodiesel is considered as clean fuel since it has almost no sulphur, no aromatics and has about 10 % built in oxygen, which helps it to burn fully. Hebbal et al. (2006) have presented the investigation on deccan hemp, a non-edible vegetable oil in a diesel engine for its suitability as an alternate fuel.

Agarwal and Agarwal (2007) conducted experiments using various blends of Jatropha oil with mineral diesel to study the effect of reduced blend viscosity on emissions and performance of diesel engine. The acquired data were analyzed for various parameters such as thermal efficiency, brake specific fuel consumption (BSFC), smoke opacity, CO_2, CO and HC emissions. While operating the engine on Jatropha oil (preheated and blends), performance and emission parameters were found to be very close to mineral diesel for lower blend concentrations. Purushothaman and Nagarajan (2009) presented work on the performance, emission and combustion characteristics of a single cylinder, constant speed, direct injection diesel engine using orange oil as an alternate fuel and the results are compared with the standard diesel fuel operation. Results indicated that the brake thermal efficiency was higher compared to diesel throughout the load spectra. Carbon monoxide (CO) and hydrocarbon (HC) emissions were lower and oxides of nitrogen (NOx) were higher compared to diesel operation. Labeckas and Slavinskas (2006) reported the comparative bench testing results of a four stroke Diesel engine when operating on neat rapeseed oil methyl ester and it's 5 %,

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10 %, 20 % and 35 % blends with Diesel fuel. The brake specific fuel consumption at maximum torque and rated power found to be higher for rapseed oil by 18.7 % and 23.2 % relative to Diesel fuel. The maximum brake thermal efficiency is higher for rapseed oil at higher load. The maximum NOx emissions increase proportionally with the mass percent of oxygen in the bio-fuel and engine speed. The carbon monoxide emissions and visible smoke emerging from the biodiesel over all load and speed ranges are lower by up to 51.6 % and 13.5 % to 60.3 %, respectively. The carbon dioxide (CO_2) is slightly higher in case of biodiesel. The emissions of unburned hydrocarbons for all bio-fuels are reported low.

In the study of Altuna et al. (2008) a blend of 50 % sesame oil and 50 % diesel fuel was used as an alternative fuel in a direct injection diesel engine. The experimental results show that the engine power and torque of the mixture of sesame oil–diesel fuel are close to the values obtained from diesel fuel and the amounts of exhaust emissions are lower than those of diesel fuel. Suresh kumar et al. (2008) presented the results of performance and emission analyses of an unmodified diesel engine fuelled with Pongamia Pinnata Methyl Ester (PPME) and its blends with diesel. Engine tests were conducted to get the comparative measures of brake specific fuel consumption (BSFC), brake specific energy consumption (BSEC) and emissions such as CO, CO_2, HC and NOx to evaluate the behaviour of PPME and diesel in varying proportions. BSFC and BSEC for all the fuel blends and diesel tested decrease with increase in load. This is due to higher percentage increase in brake power with load as compared to increase in the fuel Consumption. For the blends B20 and B40, the BSFC is lower than and equal to that of diesel respectively and the BSEC is less than that of diesel at all loads. This could be due to the presence of dissolved oxygen in the PPME that enables complete combustion; engine emits more CO for diesel as compared to PPME blends under all loading conditions. The CO_2 emission increased with increase in load for all blends. The lower percentage of PPME blends emits less amount of CO_2 in comparison with diesel. Blends B40 and B60 emit very low emissions. This is due to the fact that biodiesel in general is a low carbon fuel and has a lower elemental carbon to hydrogen ratio than diesel fuel. HC emission decreases with increase in load for diesel and it is almost nil for all PPME blends except for B20 where some traces are seen at no load and full load. The NOx emission for all the fuels tested followed an increasing trend with respect to load. The reason could be the higher average gas temperature, residence time at higher load conditions.

In an experiment on a kirloskar single cylinder diesel engine with 10-20 % palm oil bio-diesel, Naveen and Dhuwe (2004) reported significant reduction in smoke level. Lapuerta et al. (2007) analyzed diesel engine emissions when using biodiesel fuels as opposed to conventional diesel fuels. The engine emissions from biodiesel and diesel fuels are compared, paying special attention to the most concerning emissions, nitric oxides and particulate matter. Some of the important outcomes are: at part load operation, no differences in power output, since an increase in fuel consumption in the case of biodiesel would compensate its reduced heating value. There is slight increase of NO_X with biodiesel because of more oxygen content of biodiesel and at higher temperature it leads to increase NO_x. There is a sharp reduction in particulate emissions with biodiesel as compared to diesel fuel. CO is usually found to significantly decrease with biodiesel. A more complete combustion caused by the increased oxygen content in the flame coming from the biodiesel molecules has been pointed out as the main reason.

Some researchers worked to find the effect of viscosity on emissions and performance of diesel engine Agarwal et al. (2001), Gangwar et al. (2008) and Choudhary et al. (2008). Emission parameters such as smoke NOx and CO_2 were found to have increased with increasing proportion of Jatropha oil in the blends compared to diesel. They found Jatropha oil to be a promising alternative fuel for compression ignition engines. Thermal efficiency was lower for unheated Jatropha oil compared to heated Jatropha oil and diesel. CO_2, CO, HC, and smoke opacity were slightly higher for neat Jatropha oil compared to that of diesel, but it were significantly less with Jatropha and other specie's bio-diesel. These emissions were found to be close to diesel for preheated Jatropha oil.

2. Experimental setup for performance testing

The setup consists of four cylinders, four stroke, Tata Indica diesel engine connected to eddy current type dynamometer for loading. The engine test setup specifications are given in Table 1, actual test setup is shown in Figure 1. The setup enables study of engine performance for various parameters such as torque, brake power, specific fuel consumption, brake thermal efficiency, opacity and p-θ diagram. The main aim of this experiment is to investigate the suitability and effect on performance of blending of biodiesel with gasoline diesel fuel.

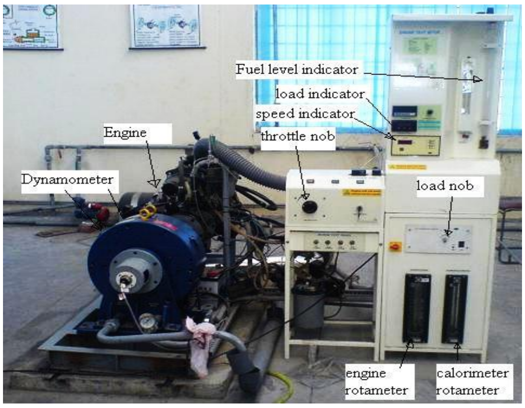

Figure 1: Actual Experimental setup.

Preparation of biodiesel blends

Calorific value of petroleum diesel = 42000 kJ/kg.
Calorific value of biodiesel = 37000 kJ/kg.
Density of petroleum diesel = 800 kg/m^3.
Density of biodiesel = 891 kg/m^3.

Table 1: Specifications of the engine test setup

S.No.	Component	Specifications
1	Engine	Tata Indica, 4 Cylinder, 4 Stroke, water cooled, Power 39kW at 5000 rpm, Torque 85 NM at 2500 rpm, stroke 79.5mm, bore 75mm, 1405 cc, CR22
2	Dynamometer	eddy current, water cooled
3	Temperature	Input RTD PT100,Range 0–100 ^{0}C,
	transmitter	Output 20 mA and , Input Thermocouple, Range 0–1200 ^{0}C,
4	Piezo sensor	Range 5000 PSI,
5	Air box	M S fabricated with orifice meter and manometer
6	Load indicator	Digital, Range 0-50 Kg, Supply 230VAC
7	Engine indicator	Input Piezo sensor,crank angle sensor, Input Piezo sensor, Communication RS 232, Crank angle sensor, No. No. of channel 2,
8	Software	Enginesoft
9	Temperature	Type RTD, PT100 and
	sensor	Thermocouple Type K
10	Fuel flow transmitter	DP transmitter, Range 0-500 mm
11	Air flow	Pressure transmitter,
	transmitter	Range (-) 250 mm WC
12	Load sensor	Load cell, type strain gauge,
		Range 0-50 Kg

Table 2: Description of different blends of biodiesel

Blend	Amount of	Amount of	Calorific value	Resultant
	Diesel (ml)	Bio diesel	of blend	Density
		(ml)	(kj/kg)	(kg/m^3)
Diesel	2000	0	42000	800
B-10	1800	200	41500	809
B-20	1600	400	41000	818
B-30	1400	600	40500	827

On this engine experiments are performed with different blends of biodiesel (pure diesel, B-10, B-20, and B-30). Jatropha biodiesel were prepared in our IC Engines laboratory. These blends are prepared in quantity of 2 liter each by mixing required quantity of biodiesel in petroleum diesel. There description of biodiesel blends is shown in Table 2.

3. Result and discussions on performance testing

Variation of Torque v/s Engine Speed

Figure 2 shows the variation of torque with speed for pure diesel and biodiesel blends of jatropha biodiesel. Variation of torque for different blends and pure diesel at a particular engine speed is within a very narrow range. In case of both biodiesel blends and pure diesel, initially the torque rises sharply with increase in engine speed up to 2500 rpm. Between speed 2500 to 4000 rpm the variation or torque with speed remain almost constant. Further increase in speed causes decrease in torque. The pattern is almost same for all blends. At initial speed biodiesel have more torque especially jatropha biodiesel has more torque. Almost similar pattern has obtained for all percentage of blends.

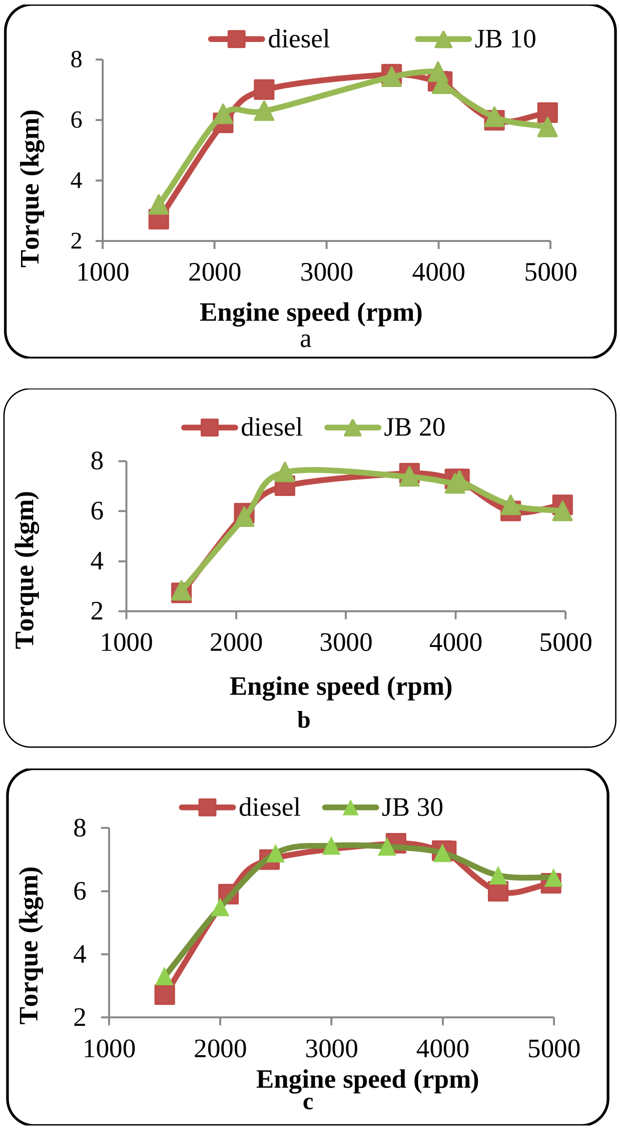

Figure 2: Comparison of Torque v/s Speed for different biodiesel blends of Jatropha oil

Variation of Brake Power v/s Speed

The variation of brake power vs. speed for both blends in comparison to pure diesel is shown in Figure 3. The Brake Power increases proportionally to engine speed in the range of 2000 to 4000 rpm. In this speed range variation of brake power is between 6-32 kW. For more than 4000 rpm there is fluctuating variation in brake power among the biodiesel blends. The variation of brake power is almost negligible for all types of blends and pure diesel for upto 4000 engine rpm. Between 4000 to 5000 rpm biodiesel blends are having slightly higher brake power as compared to pure diesel. At initial speed break power obtained is more in case of biodiesel. Except initial speed thumba biodiesel has more power compare to jatropha biodiesel.

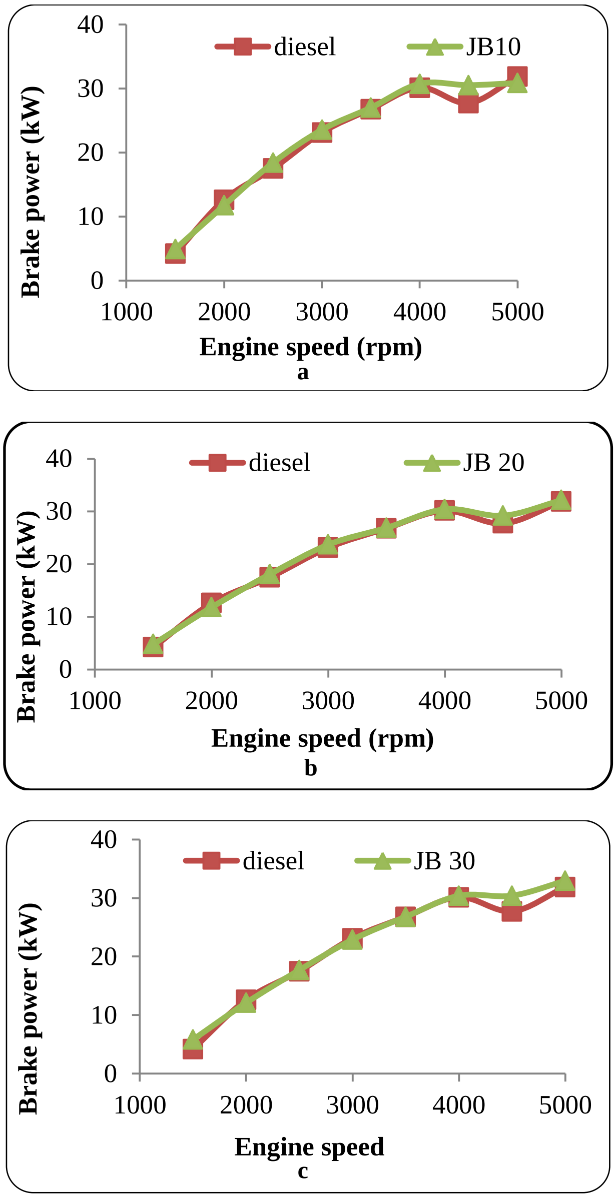

Figure 3: Comparison of Brake Power v/s Speed for different biodiesel blends of Jatropha oil

Brake Thermal Efficiency v/s Speed

Figure 4 shows comparison of Brake thermal efficiency vs. speed for different biodiesel blends of jatropha oil in comparison to diesel respectively. The maximum value of brake thermal efficiency for all blends & pure diesel is at 2000 rpm. For all blends of both oils variation of brake thermal efficiency is higher as compared to pure diesel for wide range of engine speed. The maximum thermal efficiency is achieved by using JB-30 blend is around 26.9 % at 2000 rpm which is 5 % higher as compared to pure diesel. The brake thermal efficiency is almost constant between rpm range of 2000 to 4000, and it decreases sharply with further increase in rpm and with increase in percentage of biodiesel blending the brake thermal efficiency increase for wide range of engine rpm. Jatropha oil exhibits comparatively higher efficiency for all speed range than pure diesel with all blends. Biodiesel blend of 30% shows much higher efficiency than diesel fuel.

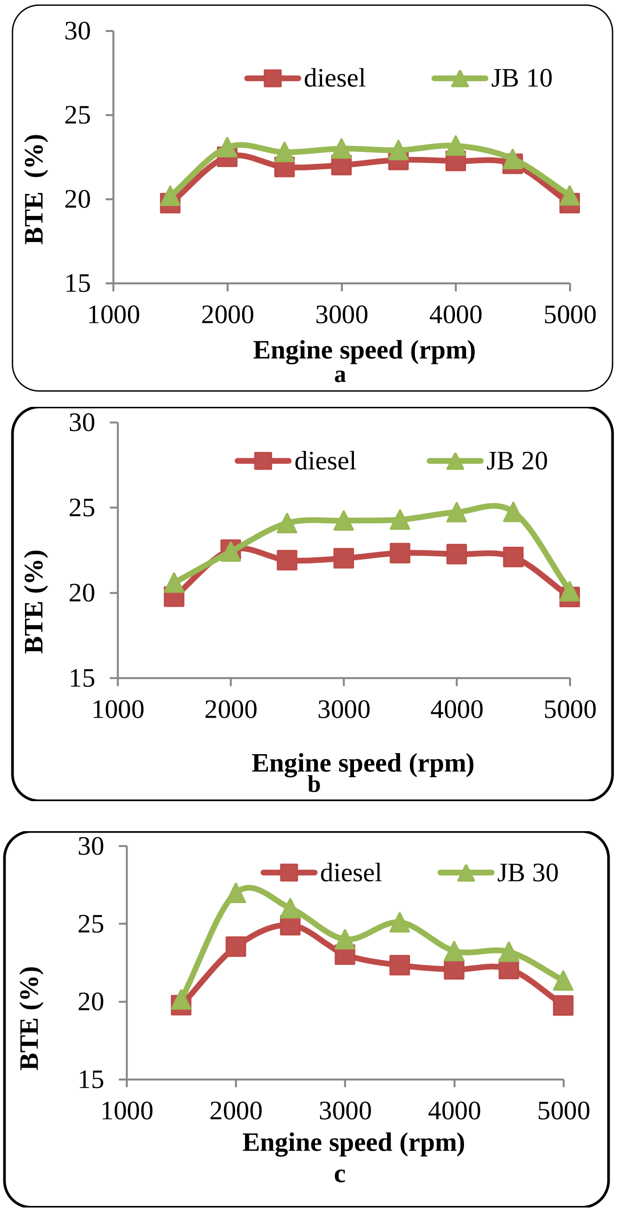

Figure 4: Brake Thermal Efficiency v/s Speed for different biodiesel blends of Jatropha oil

Smoke Opacity v/s. Speed

To understand the pollution aspect of biodiesel the variation of opacity vs. speed are shown in Figure 5. The smoke opacity value for pure diesel is slightly higher as compared to all type of blends for wide range of engine rpm. For all biodiesel blends the opacity value increases from 10 to 60 % between the speed ranges of 2000 to 3500 rpm. There is no significant change in opacity value for above 4000 rpm engine speed. The trend regarding variation of opacity with respect to speed is almost similar for all type of blends and further the variation of opacity value of different blend at a particular rpm is almost negligible. Except initial speed opacity of biodiesel blends have less value than diesel oil. This is due to better combustion property of biodiesel.

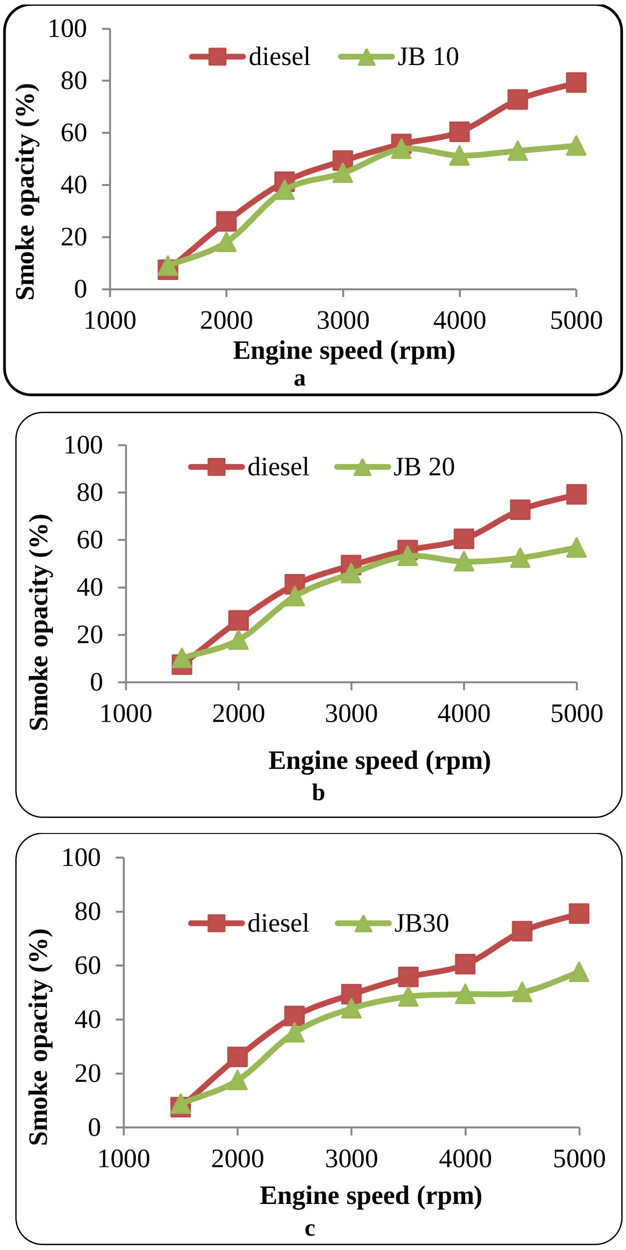

Figure 5: Comparison of Opacity v/s Speed for different biodiesel blends of Jatropha oil

4. Conclusions

From the engine performance testing it can be concluded that the performance parameters and emission characteristics for biodiesel (jatropha) are better results than the diesel oil. In this work performance of biodiesel is compared by the parameters like brake power, torque, brake thermal efficiency, specific fuel consumption and emission are characterized by opacity measurement. Some advantages obtained for biodiesel are:

At low speed more torque is obtained for biodiesel and torque almost constant for wide range of speed for both diesel and biodiesel blends. Maximum torque obtained for jatropha oil is 7.5 kg-m at 2500 rpm and maximum percentage increase in torque is 30% more than the diesel oil which is obtained for 30% blend at 1500 rpm.

More brake power is obtained at initial speed and it is nearly constant for 2500 to 4000 rpm. The maximum brake power achieved is 35 kW at 5000 rpm for biodiesel a blend of 10%. Maximum percentage increase obtained for biodiesel of 30% blend is 3.5% at 1500 rpm.

Except at starting speed more brake thermal efficiency has obtained for higher speeds. For 10% blend of biodiesel there is not much difference in diesel and biodiesel. For higher blend biodiesel has much better efficiency than diesel oil. Maximum brake thermal efficiency increased is 1.98% for biodiesel at 2000 rpm.

Lower value of opacity has obtained for biodiesel than diesel oil at higher speeds. Maximum reduction in opacity obtained is about 35 % for biodiesel.

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