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Performance and Emission Characteristics of Direct Injection Diesel Engine using Mixture of Biodiesels Prepared from Jatropha and Waste Cooking Oil

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ABSTRACT

The search for alternative fuel has become almost compulsory due to limited resource of fossil fuel and fast growth of vehicular population. Biodiesels (esters of vegetable oil) produced from non-edible seeds have become one of the options available for alternative fuel. Absence of sulphur and aromatic compounds in biodiesel has a positive substitution effect. Adding biodiesel to mineral diesel has a positive impact on the local environment by reducing hydrocarbon and particulate emission, but a negative impact on NOx. The mixture of two different bio diesel has been chosen as the fuel sample to overcome the problem of the shortage of perticular type of biodiesel. Thus our dependacy will not be limited on perticular type of biodiesel. Biodiesel can be obtained from locally available non-edible seeds or waste oil also. In this investigation, two types of biodiesels produced from Jatropha and waste cooking oil have been mixed in equal proportions and blended with diesel in different proporions i.e. 10%, 20%, 30%, 40%, 50%, 75% , 100% of biodiesel which is termed as JWB10, JWB20, JWB30, JWB40, JWB50, JWB75, JWB100 respectively. These fuel samples have been tested on diesel engine. The best performance of engine has been observed around 20% blend of biodiesel in mineral diesel. It is also found that emissions of carbon monoxide and un-burnt hydrocarbon reduce as load increases for all the blends of bio-diesel tested on the engine up to 60-80% of full load respectively beyond that these emissions further increase. It has been found that nitrogen oxide emission increases slightly as the engine load increases on the engine up to 80% of full load beyond that it further decreases. This may be due to the presence of oxygen available in bio-diesel. Hence mixture of bio-diesels can also be used as potential alternative fuel in future.

Keywords: Alternative fuels, Blend of Biodiesel, Emission, Mixture of biodiesels, Jatropha, JWB, waste cooking oil.

1. INTRODUCTION

Many investigators have attempted to replace diesel with a substitute such as vegetable oils and biodiesels. Heywood [1] has reviewed the future options for fuels for automotive engines and has suggested that the impacts of fuel on engines depend on different phases and time frame. The period from 1980-1990 was completely dominated by fuels from natural petroleum and uses of alternative fuels were only in token quantities. From 1990-2010, the dominance of fuels produced from natural petroleum and increase of contribution of alternative fuels were continued. From 2010-2030, amounts of fuels from natural petroleum and alternative fuels become comparable. After 2030, alternative fuel will dominate. Mc Donnel et al. [2] have investigated the use of semi refined rapeseed oil on a diesel engine and have found that the engine performance is better at 25% blend. But the use of rapeseed oil for a longer period of time has been found to shorten the life of injector due to the deposit of carbon with no wear on engine. Kalam & Masjuki [3] have carried out experiments using Palm biodiesel on an indirect injection, naturally aspirated four cylinder compression ignition engine.

It has been observed that as palm bio diesel increases in fuel sample, brake power increases. Jindal et al. [4] have studied the effect of engine design parameters such as compression ratio, fuel injection pressure jointly on the performance of diesel engine using Jatrophamethyl ester and have found that the combined increase of compression ratio and injection pressure, increases brake thermal efficiency and reduces brake specific fuel consumption with lower exhaust emissions. Dhar & Agarwal [5] have investigated the effect of large scale implementation of karanja biodiesel in transportation engines on lubricating oil degradation and have found the higher increase in density, carbon residue and ash content in karanja bio diesel fuelled engine's lubricating oil in comparison to diesel. Utlu et al. [6] have experimentally investigated the performance and emissions of turbocharged direct injection diesel engine using biodiesel (waste frying oil methyl ester WFOME) as fuel. It has been found that specific fuel consumption of WFOME is increased to 14.34%, emission values are decreased to 17.14% and 1.45% for Carbon Monoxide (CO) and Nitrogen oxides (NOx) respectively. Smoke intensity is increased in average 22.46% for the utilization of WFOME compared to diesel fuel. Kalbande et al. [7] have tested biodiesel produced from raw jatropha and karanj oil and its blends with diesel for power generation in a 7.5 KVA diesel engine generator set.

The overall efficiency of the generator for 6,000 W loading conditions has been improved for jatropha and karanj biodiesel blends and has been found in the range of 31–33% and 33–39%, respectively. Biodiesel blends B80 and pure biodiesel of karanja have produced more power, and maximum overall efficiency in comparison to diesel fueled generator. The overall efficiency on jatropha-biodiesel-blended fuel is found to be less than that of diesel-fueled generator. Sahoo et al. [8] have tested ten fuel blends (Diesel, B20, B50 and B100) of Non-edible jatropha (Jatropha curcas), karanja (Pongamia pinnata) and polanga (Calophylluminophyllum) oil based methyl esters for their use as substitute fuel for a tractor engine and found that maximum power increased when 50% jatropha biodiesel and diesel blend was used at rated speed.

Brake specific fuel consumptions for all the biodiesel blends with diesel increases with blends and decreases with speed. There is a reduction in smoke for all the biodiesel and their blends when compared with diesel. Baiju et al. [9] have experimentally investigated the performance and exhaust emission characteristics of the engine using petro-diesel as the baseline fuel and several blends of diesel and biodiesel as test fuels. Results show that methyl esters of Karanja oil produced slightly higher power than ethyl esters. Exhaust emissions of both esters were almost identical. Sanjid et al. [10] have worked on palm biodiesel (PB) and jatropha biodiesel (JB) produced from the respective crude vegetable oils through transesterification. The experimental results of the research carried out to evaluate the BSFC, engine power, exhaust and noise emission characteristics of a combined palm and jatropha blend in a single-cylinder diesel engine at different engine speeds ranging from 1400 to 2200 rpm.

Though the PBJB5 and PBJB10 biodiesels showed a slightly higher BSFC than diesel fuel, all the measured emission parameters and noise emission have been significantly reduced, except for NO emission. CO emissions for PBJB5 and PBJB10 were 9.53% and 20.49% lower than for diesel fuel. By contrast, HC emissions for PBJB5 and PBJB10 are 3.69% and 7.81% lower than for diesel fuel. The sound levels produced by PBJB5 and PBJB10 are also reduced by 2.5% and 5% compared with diesel fuel due to their lubricity and damping characteristics. Arbab et al. [11] have reviewed the fuel properties, engine performance and emission characteristics of commonly used different vegetable (jatropha, palm, coconut, cottonseed, sunflower, soybean and canola/rapeseed) based biodiesel derived from experimental results at different conditions performed worldwide. The potential guidelines to improve engine performance and emission characteristics have been discussed using different biodiesels and their blends as well.

It has been concluded that single biodiesel cannot improve both engine performance and emission at a time, but blend of two or more biodiesels may be able to achieve this goal. In this respect, a blend of jatropha and coconut biodiesel has been suggested. This study provides a comparative baseline to make an easy comparison among the biodiesels in respect to fuel properties, engine performance and emission characteristics. Yadav and Sinha [12, 13, 14] have experimentally investigated the performance and emissions characteristics of direct injection diesel engine using biodiesels produced from waste cooking oil, karanja oil and mixture of four biodiesels (AJKWB) as fuel. Maximum brake thermal efficiency and minimum brake specific fuel consumption have been observed with 20% blend of biodiesels/mixture of biodiesels in conventional diesel at about 80% of rated brake load applied on the engine. Emissions of CO, UHC have been found to be less than conventional diesel although NO_X were found little higher than conventional diesel.

2. EXPERIMENTAL METHOD

2.1 Preparation of fuel sample

In order to evaluate mixture of biodiesels (JWB) as diesel engine fuel, first the mixture of two biodiesels (prepared from Jatropha and waste cooking oil) is prepared by mixing them in equal proportion by volume and then various blends of this mixture (JWB) in conventional diesel have been prepared. The blends are designated by “JWB”. For example, JWB75 indicates that it contains 75% of mixture of biodiesels and remaining 25% is conventional diesel. For finding the optimum ratio, the blends JWB10, JWB20, JWB30, JWB40, JWB50, JWB75 and JWB100 have been prepared. Experiments have been conducted with JWB0 (Pure diesel) and JWB100 (Pure mixture of biodiesels) also.

The properties of fuel samples have been measured for diesel and biodiesel prepared from jatropha and waste cooking oil. The properties of different blends of mixtures of biodiesel, mixture rule have been used and are given in table 1.

Table 1: Properties of diesel and mixtures of Jatropha-waste cooking oil biodiesels (JWB)

Fuel	Density kg/m^3 (at 40°C)	Viscosity mm^2/sec (at 40°C)	Flash point (°C)	Cloud point (°C)	Pour point (°C)	Heating value (MJ/kg)
Diesel	815	2.75	50	2.5	-11.5	43.37
JWB100	873.5	4.99	154	4.5	0.5	39.099

2.2 Experimental Set-up

All fuel samples have been tested on diesel engine at National Institute of Technology, Raipur, Chhattisgarh, India. The schematic diagram of test engine set-up is shown in figure 1. The specifications of test engine are given in table 2.

Table 2: Specification of Diesel engine

S No	Parameter	Details
1	Make	Kirloskar
2	Model	1M 11x11
3	Engine type	Single cylinder, vertical, constant speed diesel engine
4	Bore and stroke	110mm x110mm
5	Swept Volume	1045.8 cc
6	Compression Ratio	16.5:1
7	Rated power	7.46 kW (10 BHP) at 1500 rpm
8	Engine cooling	Water cooled

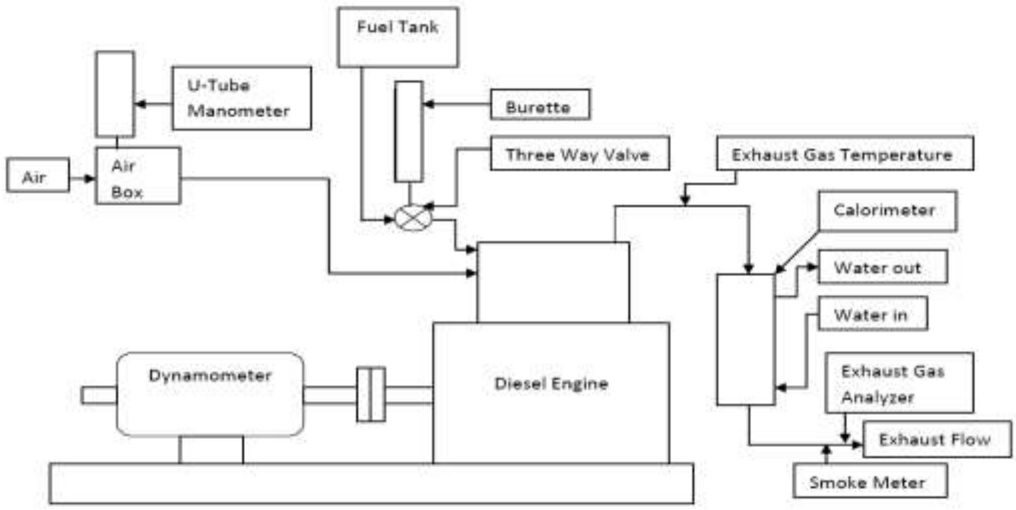

Figure1: Schematic diagram of test engine set-up

3. PERFORMANCE & EMISSION MEASUREMENT

The performance parameters such as brake thermal efficiency, brake specific fuel consumption and exhaust temperature have been measured by running the engine using conventional diesel. The same experimental procedure has been repeated with different fuel samples JWB10, JWB20, JWB30, JWB40, JWB50, JWB75, JWB100. The emission characteristics have been studied by measuring carbon monoxide, un-burnt hydrocarbon, nitrogen oxides, smoke opacity etc. in the engine exhaust.

4. RESULTS & DISCUSSION

The results of experimental investigation are given below:

4.1 Brake thermal efficiency (BTE)

Figure 2 shows the variation of BTE and engine load for diesel and diesel-biodiesels (JWB) blend. It is observed that as the load increases, BTE increases for all the fuel samples tested including diesel up to 80 % of rated brake load, beyond this load it further reduces. This may be due to increase in power developed with increase in load associated with less increase in energy input. It is observed that BTE of engine is higher for diesel than JWB100 for all the brake loads applied on the engine. It may be due to less calorific value of biodiesel.

As the biodiesel content increases in the fuel sample, BTE increases up to JWB20 blend, beyond this blend, it further reduces for all the loads. It may be due to larger concentration of biodiesel (above JWB20), in the blend which tends to reduce the net calorific value of the mixture leading to increase in fuel consumption as compared to JWB0-JWB20 fuel samples. The BTE of engine for JWB10 and JWB20 fuel samples is observed to be higher than diesel (JWB0) for all the brake loads applied on the engine (table 3). The highest value of efficiency has been found for JWB20 fuel sample as 28.07% at 80% of rated brake load which is 3.988 % higher than diesel for same load.

After mixing biodiesel in diesel oil, the brake thermal efficiency of the engine improves as biodiesel provides better lubricity to the fuel resulting in lower loss of power in fuel pump. The oxygen molecules available in esters enhance the combustion quality. The fuel samples JWB10 and JWB20 perform better than diesel. JWB100 blend is not observed to be better for any load as compared to diesel, this may be due to high viscosity and improper mixing of fuel with air.

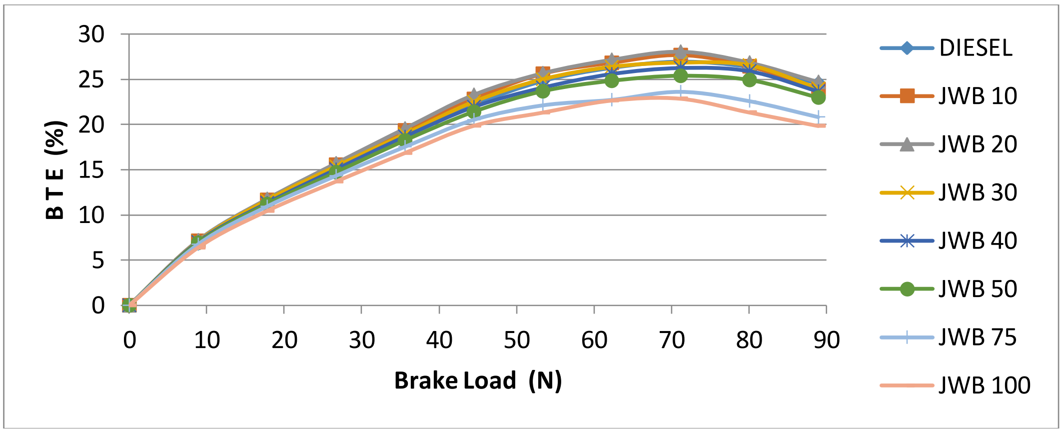

Figure 2: Variation of brake thermal efficiency with brake load for the different blends of JWB in conventional diesel

4.2 Brake specific fuel consumption (BSFC)

The variation of BSFC with brake load for different blends of bio-diesel (JWB) and mineral diesel in the test engine is presented in figure 3. It is observed that BSFC decreases with increase in the brake load for all the blends of fuel tested on the engine till 80% of the rated load (table 3), beyond that it further increases. This may be due to the fact that as brake load on engine increases, the brake power increases for better utilization of injected fuel. The increase in brake power is more as compared to the increase in fuel consumption resulting in lower BSFC. The BSFC of engine for diesel (JWB0) is found to be lower than JWB30-JWB100 at all the brake loads applied on the engine. It may be due to the less heat content of biodiesel.

As the biodiesel content increases in the fuel sample, BSFC of the engine reduces up to JWB20 sample for most of the brake loads, and beyond this, it further increases. It may be due to the supply of more quantity of fuel compared to that of conventional diesel. The BSFC of engine for JWB20 fuel sample is observed to be lower for most of the brake loads applied on the engine. The lowest value of BSFC is found as 0.3018 kg/kWh for diesel (JWB20 sample) at 80% rated brake load.

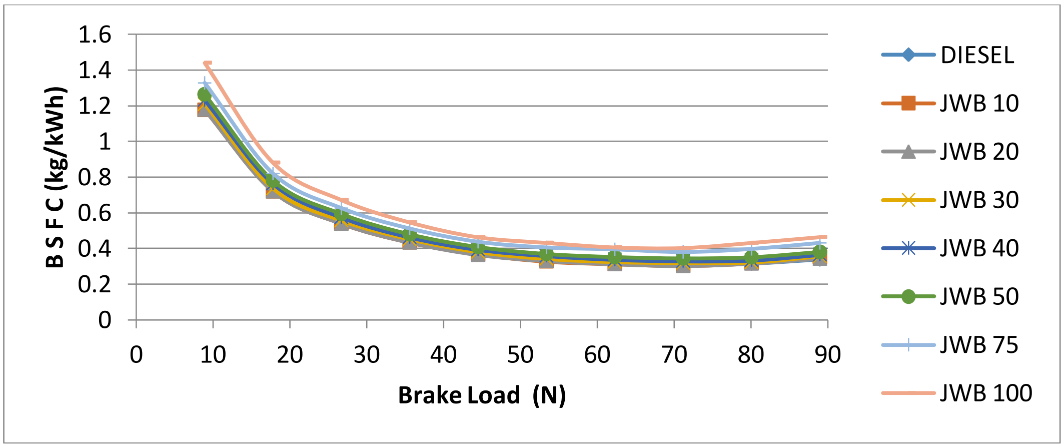

Figure 3: Variation of brake specific fuel consumption with brake load for the different blends of JWB in conventional diesel

4.3 Exhaust Gas temperature (EGT)

The variation of EGT with brake load for different blends of JWB and conventional diesel in the exhaust of the test engine is shown in figure 4. It is observed that EGT increases with the increase in engine load for all the fuel samples tested. It is also observed that EGT of most of the JWB samples except JW10-JW30 is found to be lower than the conventional diesel for different brake loads applied on the engine. This may be due to lower heat content of JWB in comparison to diesel.

As the JWB content increases in fuel sample, EGT increases up to JWB30 sample and after that it reduces. It may be due to the reducing trend of calorific value of fuel samples. The high EGT enhances the oxidation of un-burnt hydrocarbon in tail pipe. The EGT of JWB10-JWB30 is found higher than diesel (JWB0) for most of the brake loads applied on the engine. The maximum value of EGT is observed as 522°C for JWB30 sample at full load which is 1.341% higher than diesel at full load.

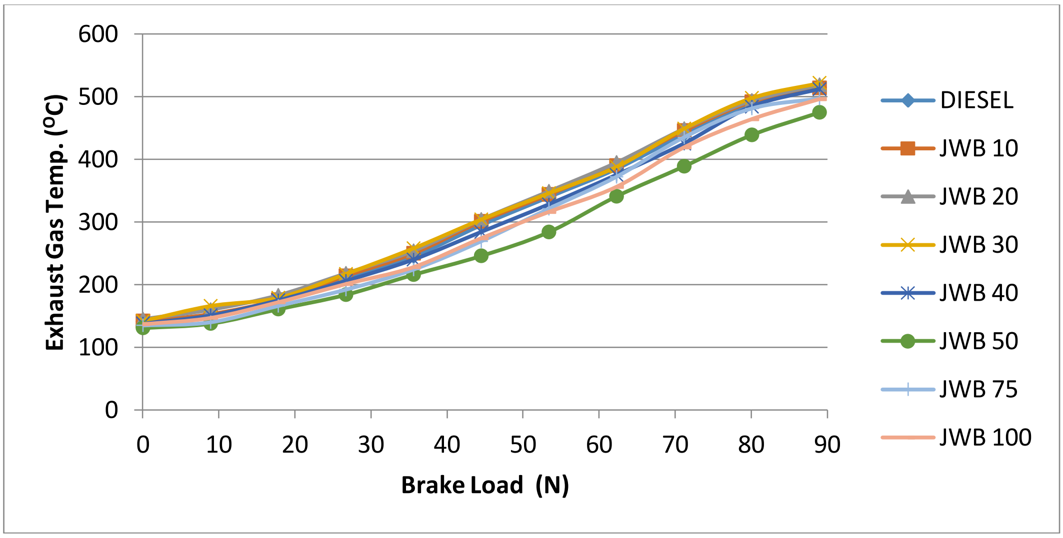

Figure 4: Variation of exhaust gas temperature with brake load for the different blends of JWB in conventional diesel

4.4 Carbon monoxide (CO) Emission:

Figure 5 shows the variation of CO in exhaust gas with brake load for different blends of JWB and conventional diesel in the test engine. It has been found that CO reduces in engine exhaust as load increases up to 60-70% of rated brake load and after that it further increases. It may be due to improper combustion in higher range of load for all the samples tested on the test engine. As the JWB content increases in the fuel samples, CO emission in exhaust reduces up to JWB20 and after this blend, it further increases. It may be due to increase in viscosity and decrease in heat content of fuel. The minimum emission of CO is observed as 0.021% for JWB100 sample at 70% of brake load which is 16% lower than the CO emission using diesel fuel in test engine.

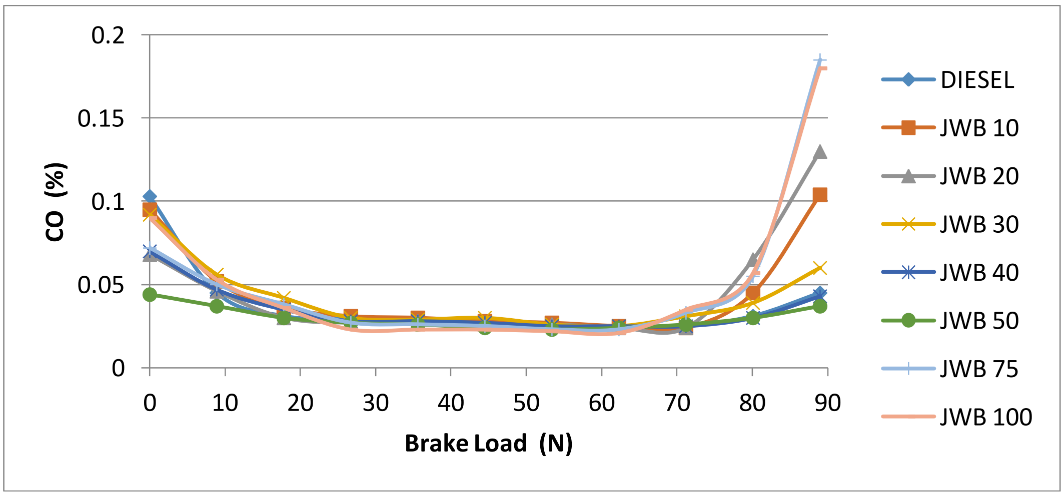

Figure 5: Variation of carbon monoxide with brake load for the different blends of JWB in conventional diesel

4.5 Un-burnt hydrocarbon emission (UHC)

Figure 6 shows the variation of un-burnt hydrocarbon in exhaust gas with brake load for different blends of JWB and conventional diesel in the test engine. It has been observed that for most of the samples of fuel tested on engine, un-burnt hydrocarbon reduces with increase of load up to 60-70% of engine load, after that it further increases. It may be due to poor combustion at higher load.It is observed that UHC emission for JWB10- JWB100 sample is lower than diesel for most of the brake load applied.

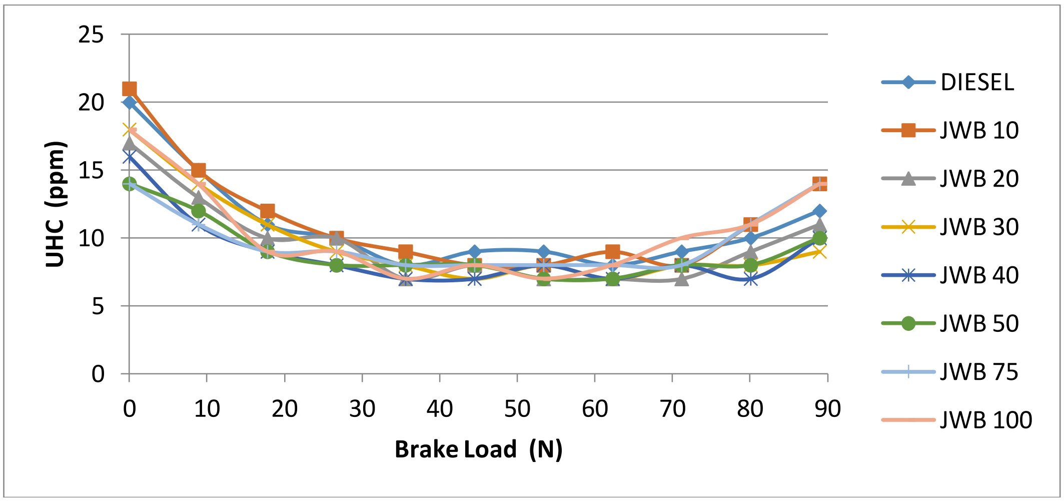

Figure 6: Variation of un-burnt hydrocarbon with brake load for the different blends of JWB in conventional diesel

4.6 Nitrogen oxides (NO_x) emission

Figure 7 shows the variation of nitrogen oxides (NO_x) in exhaust gas with brake load for different blends of JWB and conventional diesel in the test engine. It has been observed that as load increases, NO_x emission in exhaust increases till 80% of rated load, beyond that it further reduces for most of the samples of fuel tested. It may be due to improper combustion at higher load. The NO_x emission in exhaust gas is found to be higher for most of the fuel samples in comparison to diesel at most of the brake loads applied on the engine.The maximum concentration of NO_x has been found 490 ppm for JWB30 blend at 80% of rated load which is 25.96% higher than diesel. It may be due to oxidation of nitrogen available in fuel and/or air at higher exhaust gas temperature. The NO_x emission increases as biodiesel content in the fuel increases for the samples JWB10-JWB30, beyond that it further reduces. It may be due to proper combustion of fuel samples having low percentage of biodiesel content.

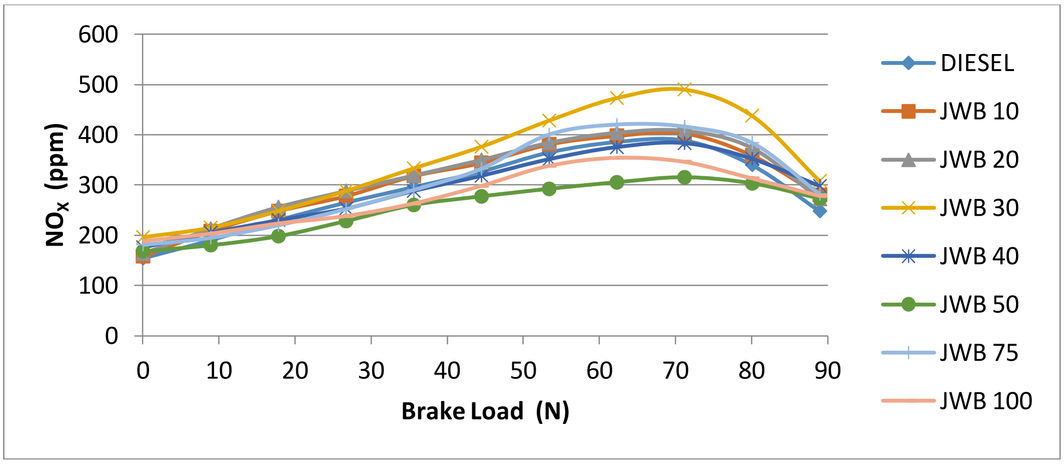

Figure 7: Variation of nitrogen oxides with brake load for the different blends of JWB in conventional diesel

4.7 Smoke emission:

Figure 8 shows the variation of smoke percentage in exhaust gas with brake load for different blends of JWB and conventional diesel in the test engine. It clearly shows that the smoke percentage increases as load increases for all the blends tested on the test engine. It may be due to the supply of more quantity of fuel and improper combustion of fuel at higher loads.

Smoke percentage is observed to be less for all the samples of JWB10-JWB100 in comparison to diesel. The maximum smoke percentage in exhaust has been found to be 64% at full load for diesel fuel which is 10.94-21.88% higher than JWB blended fuel samples. It may be due to the availability of oxygen molecules in biodiesel blended fuel which enhances combustion quality.

Table 3: Values of the best performance points and corresponding emission characteristics

Fuel Used	Performance		Exhaust Emissions			
	BTE (%)	BSFC (kg/kWh)	CO (%)	UHC (ppm)	NO_X (ppm)	Smoke Opacity (%)
Conventional Diesel (At 80% load)	26.99	0.3077	0.025	9	389	39
JWB20 (at 80% load)	28.07	0.3018	0.024	7	408	35

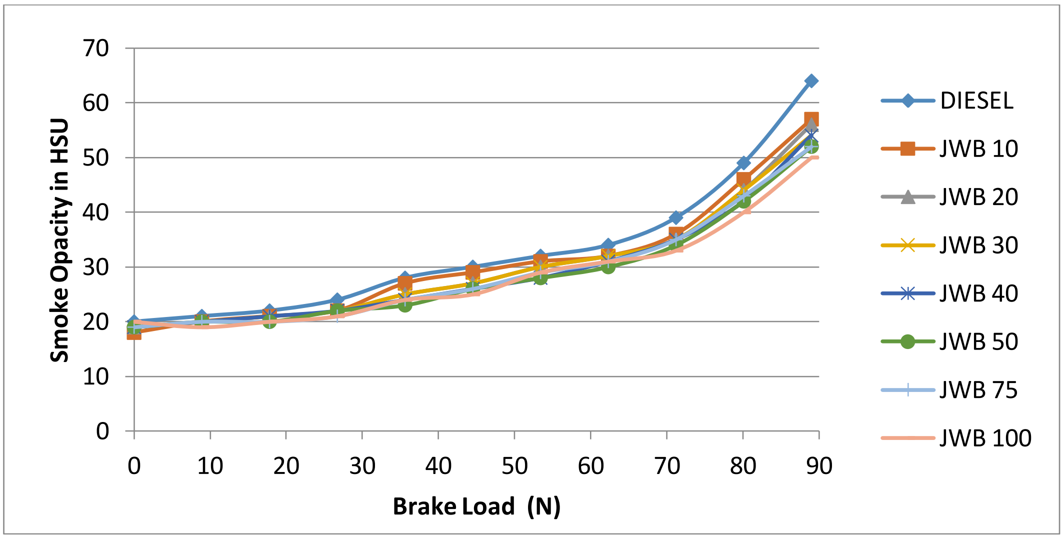

Figure 8: Variation of smoke percentage with brake load for the different blends of JWB in conventional diesel

CONCLUSION

The mixture of biodiesels prepared from jatropha and waste cooking oil is found to be potential candidate for alternative fuel for diesel engine as the performance characteristics is found to be almost similar (sometimes better) to diesel. The exhaust emission is also found to be cleaner except NOx emission which is little bit higher due to oxygen available in the biodiesel. The blended fuel sample JWB10-JWB30 can be used in diesel engine without any modification in engine hardware. The present investigation clearly shows that diesel engine can be operated with any kind of biodiesel. Thus it is not necessary to depend on some fixed type of biodiesel only.

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