EXPERIMENTAL STUDIES ON EMISSION AND PERFORMANCE OF C.I. ENGINE WITH BIODIESEL AND ITS BLENDS

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ABSTRACT:

Many researchers have done a lot of experimental studies in the field of biodiesel to find an alternative to mineral diesel. It has shown that Jatropha biodiesel can be used as an alternative fuel in Diesel engine without modification. An experimental study was carried out to find out the effect of Jatropha bio-diesel on engine performance and emissions. For this experimental setup a 7 kW single cylinder, air-cooled, constant speed direct injection diesel engine with alternator was used for the experimental work. Emissions like NO_X, CO, HC and smoke opacity were measured. Engine performance parameters such as brake thermal efficiency (BTE), brake specific energy consumption (BSEC) and exhaust gas temperature were also calculated. Results indicated that B20 have closer performance to diesel. The brake thermal efficiency for bio-diesel fuelled engine was slightly higher than diesel fuelled engine. There was increase in specific energy consumption and exhaust gas temperature with increase in bio diesel proportion in biodiesel blends. The rate of NO_X emissions from biodiesel was gradually increased by 15, 18, 16 and 11 per cent higher than that of the diesel at 2.58, 3.83, 4.99 and 5.88 BMEP (2.9, 4.3, 5.6 and 6.6 kW) load conditions respectively. The carbon monoxide reduction by biodiesel was 11, 10, 15 and 19 per cent at 2.58, 3.83, 4.99 and 5.88 BMEP (2.9, 4.3, 5.6 and 6.6 kW) load conditions. Hydrocarbon (HC) and smoke opacity from the biodiesel and its blends was found lower than diesel fuel during the whole experimental range. Exhaust gas temperature increased with increase in load and amount of biodiesel. The highest exhaust gas temperature was observed as 455ºC for biodiesel among the four load conditions. The diesel mode exhaust gas temperature was observed as 368ºC.

Keywords— diesel, biodiesel, bio-diesel blends, performance, emissions**.**

I: INTRODUCTION

The diesel engine is typically more efficient than the gasoline engine due to higher compression ratio. Diesel engines also do not suffer from size and power limitations, which the SI engine is prone to. Hence, keeping these factors into account, they are the invariable choice for industrial, heavy duty and truck/trailer engines. Buses and certain locomotives also use diesel engines. Diesel engines also find use as small captive power plant engines, tractor engines and irrigation pump sets. India, which is at a developing stage in its history, has a huge demand for diesel driven machines and unlike countries like USA, is a diesel driven economy. India is an agriculture based economy and agriculture is an energy transformation process as energy is produced and consumed in it. The production of energy is carried through process of photosynthesis in which solar energy is converted into biomass. Agriculture in India is heavily based upon petroleum and its derived products such as fertilizers and pesticides. Energy sources used in agriculture are oil and electricity whereas indirect energy sources are chemical fertilizers and pesticides. Thus, keeping the above discussion in mind it is imperative for the Indian economy to find a substitute to fuel variety of diesel engines that it is so much dependent upon so as to fulfill its journey to becoming a developed nation.

The consumption of diesel is 4-5 times higher than petrol in India. Due to the shortage of petroleum products and its increasing cost, efforts are on to develop alternative fuels especially, to the diesel oil for full or partial replacement. It has been found that the vegetable oils are promising fuels because their properties are similar to that of diesel and are produced easily and renewably from the crops. Vegetable oils have comparable energy density, cetane number, heat of vaporization and stoichiometric air–fuel ratio with that of the diesel fuel. None other than Rudolph Diesel, the father of diesel engine, demonstrated the first use of vegetable oil in compression ignition engine in 1910. He used peanut oil as fuel for his experimental engine [1]. So the use of vegetable oils as alternative fuels has been around for one hundred years when the inventor of the diesel engine Rudolph Diesel first tested peanut oil, in his compression-ignition engine. In the 1930s and 1940s vegetable oils were used as diesel fuels from time to time, but usually only in emergency situations. In 1940 first trials with vegetable oil methyl and ethyl esters were carried out in France and, at the same time, scientists in Belgium were using palm oil ethyl ester as a fuel for buses. Not much was done until the late 1970s and early 1980s, when concerns about high petroleum prices motivated extensive experimentation with fats and oils as alternative fuels. Bio-diesel (mono alkyl esters) started to be widely produced in the early 1990s and since then production has been increasing steadily. In the European Union (EU), bio-diesel began to be promoted in the 1980s as a means to prevent the decline of rural areas while responding to increasing levels of energy demand. However, it only began to be widely developed in the second half of the 1990s [2].

Vegetable oils have almost similar energy density, cetane number, heat of vaporization, and stoichiometric air/fuel ratio compared to mineral diesel fuel. However, straight vegetable oils cannot be used directly in engines. Straight vegetable oils or their blends with diesel pose various long-term operational and durability problems in compression ignition engines, e.g. poor fuel atomization, piston ring-sticking, fuel injector coking and deposits, fuel pump failure, and lubricating oil dilution etc. The properties of vegetable oils responsible for these problems are high viscosity, low volatility, and polyunsaturated character. Several techniques are proposed to reduce the viscosity of vegetable oils such as blending, pyrolysis, micro-emulsion and transesterification etc. Heating and blending of vegetable oils reduce the viscosity but its molecular structure remains unchanged hence polyunsaturated character and low volatility problems exist. It has been reported that transesterification is an effective process to overcome all these problems associated with vegetable oils [3].

Vegetable oil can be directly mixed with diesel fuel and may be used for running an engine. The blending of vegetable oil with diesel fuel in different proportion were experimented successfully by various researchers. Blend of 20% oil and 80% diesel have shown same results as diesel and also properties of the blend is almost close to diesel. The blend with more than 40% has shown appreciable reduction in flash point due to increase in viscosity. Some researchers suggested for heating of the fuel lines to reduce the viscosity. Although short term tests using neat vegetable oil showed promising results, longer tests led to injector coking, more engine deposits, ring sticking and thickening of the engine lubricant [4]. Micro-emulsification, pyrolysis and transesterification are the remedies used to solve the problems encountered due to high fuel viscosity. Although there are many ways and procedures to convert vegetable oil into a Diesel like fuel, the transesterification process was found to be the most viable oil modification process [3].

The use of vegetable oils, such as palm, soya bean, sunflower, peanut, and olive oil, as alternative fuels for diesel is being promoted in many countries [5].

China is rich in cottonseed and research on using cottonseed oil as diesel engine fuel has been intensively and widely studied there. From a technological point of view, the fuel property of cottonseed oil seems to meet the fundamental requirements of diesel engine. Y.He et al. [6] conducted tests with blend of 30% cottonseed oil and 70% diesel on diesel engine. The experimental results obtained showed that a mixing ratio of 30% cottonseed oil and 70% diesel oil was practically optimal in ensuring relatively high thermal efficiency of engine, as well as homogeneity and stability of the oil mixture. For this purpose, a modification of diesel engine structure is unnecessary, as has been confirmed by the literature. High viscosity of cottonseed oil is one of the key problems preventing its widespread application.

Deshpande [7] used blends of linseed oil and diesel to run the CI engine. Minimum smoke and maximum brake thermal efficiency were reported in this study. Barsic et al. [8] conducted experiments using 100% sunflower oil, 100% peanut oil, 50% of sunflower oil with diesel and 50% of peanut oil with diesel. A comparison of the engine performance was presented. The results showed that there was an increase in power and emissions. In another study, Rosa et al. [9] used sunflower oil to run the engine and it was reported that it performed well. Blends of sunflower oil with diesel and safflower oil with diesel were used by Zeiejerdki et al. [10] for his experimentation. He demonstrated the least square regression procedure to analyze the long-term effect of alternative fuel and I.C. engine performance.

II: EXPERIMENTAL SETUP AND METHODOLOGY

A Kirloskar make, single cylinder, air cooled, direct injection, DAF 10 model diesel engine was selected for the present research work, which is primarily used for agricultural activities and household electricity generations.

It is a single cylinder, naturally aspirated, four stroke, vertical, air-cooled engine. It has a provision of loading electrically since it is coupled with single phase alternator through flexible coupling. The engine can be hand started using decompression lever and is provided with centrifugal speed governor. The cylinder is made of cast iron and fitted with a hardened high-phosphorus cast iron liner. The lubrication system used in this engine is of wet sump type, and oil is delivered to the crankshaft and the big end by means of a pump mounted on the front cover of the engine and driven from the crankshaft. The inlet and exhaust valves are operated by an overhead camshaft driven from the crankshaft through two pairs of bevel gears. The fuel pump is driven from the end of camshaft. The detailed technical specifications of the engine are given in Table 1.

Make and Model	Kirloskar DAF 10
TYPE	single cylinder, naturally aspirated, 4 stroke, vertical, air-cooled
Rated Brake Power (kW)	7
Rated Speed (rpm)	1500
Number of Cylinder	One
Bore x Stroke (mm)	102 x 110
Compression Ratio	17.5:1
Lubrication System	Forced Feed

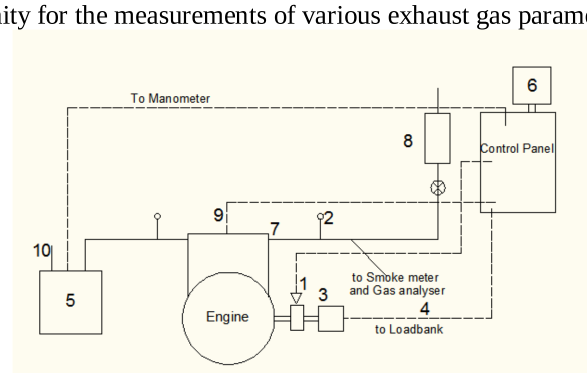
Table 1:- Specifications of the Diesel Engine

For conducting the desired set of experiments and required data together from the engine, it is essential to get the various instruments mounted at the appropriate location on the experimental setup. A two fuel tank system is used to easy switch from diesel to biodiesel or vice versa.

After finalizing the procedures for data collection and procurement of the desired instruments, they were put on a panel. A MS Control panel was fabricated and Instruments such as voltmeter, ammeter, watt meter, speed counter, six channels digital temperature display was mounted on the front side of the control panel. Electrical load bank (12 bulbs each of 500 watts and 2 bulbs each of 300 watts) mounted on the rear side of the control panel and their switches provided on the front side of the control panel.

One 50ml burette with stop cocks was also mounted on the front side of the panel for fuel flow measurements of either diesel or biodiesel fuel. The two fuel tanks were mounted on the rear side of the panel at highest position with stop cocks.

A voltmeter, ammeter and wattmeter were connected between alternator and load bank. A nut was welded on the flywheel and the photo reflective sensor was mounted on a bracket attached to engine body. The thermocouples were mounted in the exhaust manifold to measure the exhaust temperature. The AVL 437 smoke meter and AVL 4000 Di Gas Analyzer were also kept in proximity for the measurements of various exhaust gas parameters.



1. Engine Speed, 2.Exhaust Manifold Temperature,

3. Alternator , 4.Electical loading arrangement, 5. Inlet Air box, 6.Fuel Tank, 7.Engine Exhaust, 8. Muffler,

9. Fuel to Engine and 10. Fresh Air

Figure 1: Experimental set up

(1) The fuel properties

The fuel properties of the jatropha biodiesel and its blends are furnished in the table 1.

Sr. No	Properties	Diesel	Jatropha biodiesel				
			B20	B40	B60	B80	B100
1	Calorific value, MJ/kg	44.42	43.25	42.07	41.14	40.17	39.17
2	Flash point, ºC	50	58	79	104	119	194
3	Specific gravity	0.841	0.844	0.848	0.853	0.858	0.862
4	Kinematic viscosity at 40ºC, cSt	4.86	4.96	5.03	5.14	5.26	5.37
5	Carbon residue, %	0.21	0.21	0.22	0.22	0.24	0.24

Table 1: Fuel Properties of Jatropha Biodiesel and Its Blends.

III: PERFORMANCE CHARACTERISTICS

1) Specific Fuel Consumption and Specific Energy Consumption

The fuel consumption of engine was increased with increase in amount of biodiesel blends is shown in Figure. 2. In the case of jatropha biodiesel alone, the fuel consumption was about 14 per cent higher than that of diesel. This may be due to higher specific gravity and lower calorific value of the biodiesel fuel as compared with diesel fuel. The calorific value of the jatropha biodiesel was about 13 per cent lower than that of diesel fuel. The percent increase in fuel consumption of biodiesel blends (B20 to B80) ranged from 2 to 12 per cent than diesel fuel due to decrease in calorific value of these fuels.

The specific fuel consumption was calculated by fuel consumption divided by the rated power output of the engine. The percent increase in specific fuel consumption ranged from 2 to 13 for B20 to B100 fuels. The range of increase in fuel consumption was found to be similar under all load conditions. The percent increase in specific fuel consumption was increased with decreased amount of diesel fuel in the blended fuels. This may due to lower heating value of the fuels and higher mass of fuel flow to meet the engine loads.

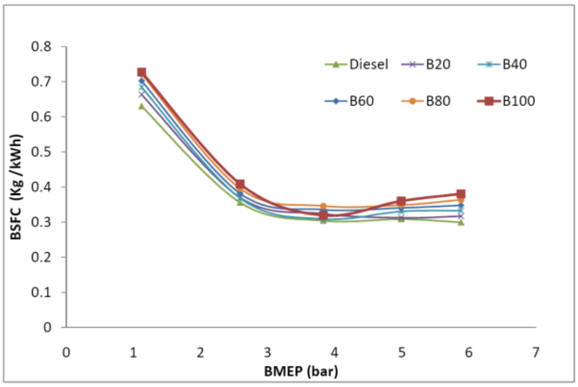


Figure 2: BSFC v/s BMEP with different biodiesel blends

Since Brake Specific Fuel Consumption is not a very reliable parameters to compare the performance of two different fuels since density and calorific value of both the fuel are significantly different. Therefore, brake specific energy was taken as a parameter to compare the energy requirement for producing unit power in case of different test fuels. It can be observed from figure 3 that the BSEC is higher at medium load for biodiesel and it is lower at high load. This means biodiesel performance for BSEC of biodiesel gives nearer results to diesel fuelled engine.

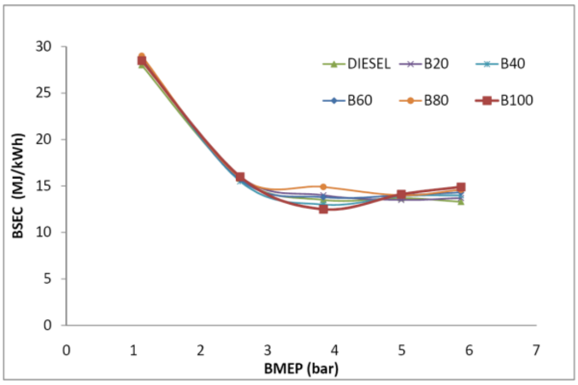


Figure 3: BMEP v/s BSEC with different biodiesel blends

2) <u>Brake Thermal Efficiency</u>

The brake thermal efficiency with biodiesel and its blends was found to be slightly higher than that of diesel fuel at tested load conditions. It varied from 23 to 26.0 per cent for diesel fuel alone. There was no difference between the biodiesel and its blended fuels on efficiencies. The brake thermal efficiencies of engine, operating with biodiesel mode were 22.5, 28, 26, and 23.5 per cent at 2.9, 4.3, 5.6 and 6.6 kW (2.58, 3.83, 4.99, and 5.88 BMEP) load conditions respectively (Figure 4).

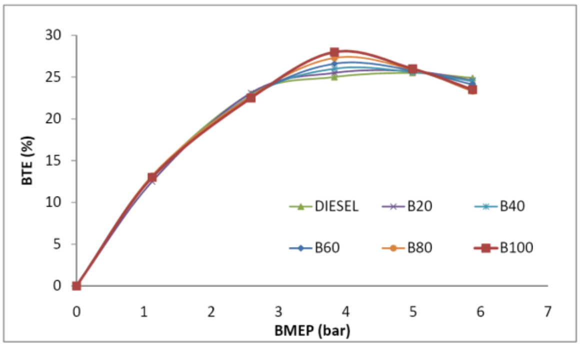


Figure 4: BTE Vs BMEP with different biodiesel blends

3) <u>Exhaust Gas Temperature</u>

The exhaust gas temperature gives an indication the amount of waste heat going with exhaust gases. The exhaust gas temperature of the different biodiesel blends is shown in Figure 5. The exhaust gas temperature of B100 varies from 10 to 14 per cent higher than that of diesel at all load conditions. The highest exhaust gas temperature was observed as 455ºC for biodiesel among four load conditions. The diesel fuel mode exhaust gas temperature was observed as 368ºC (Figure 5).

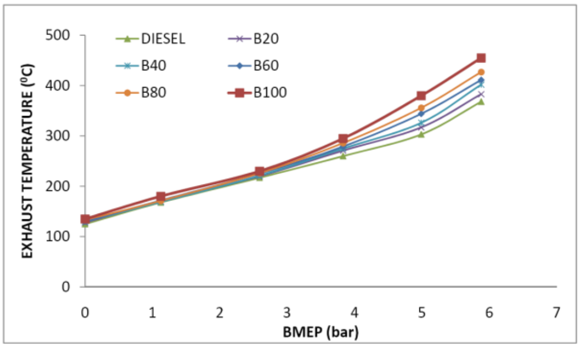


Figure 5: Exhaust Temperature v/s BMEP with different biodiesel blends

IV: EMISSION CHARACTERISTICS

1) <u>NO_X Emission</u>

The variations of NO_X emissions for all the test fuels are shown in Figure 6. The NO_X emissions increased with the increasing engine load, due to higher combustion temperature. This proves that the most important factor for the emissions of NO_X is the combustion temperature in the engine cylinder.

The NO_X emission from engine with different jatropha biodiesel blended fuels and biodiesel is shown in Figure. 6. The NO_X emission increased for biodiesel by 15, 18, 16 and 11 per cent higher than diesel fuel at 2.9, 4.3, 5.6 and 6.6 kW

(2.58, 3.83, 4.99, and 5.88 BMEP) load conditions. The percentage of increase in NO_X concentration for blended biodiesel fuels were observed as 1 to 18 per cent when compared with diesel fuel. The NO_X emission increased with increase in biodiesel amount in the blended fuels and also found that NO_X emission from the biodiesel fuel was higher than that of diesel. An important observation is that Biodiesel blend B20 has lower NO_X emissions than the baseline data for diesel. However, the increase in NO_X concentration is the main problem in biodiesel and it can be reduced by making suitable change in the engine parameters.

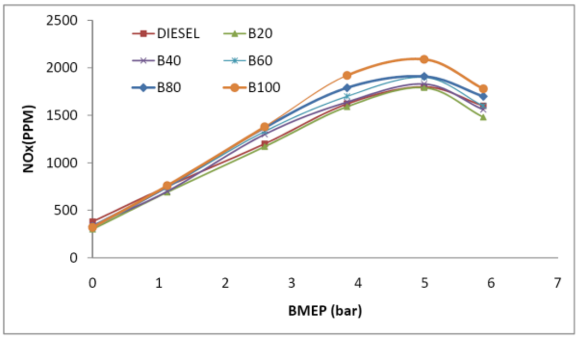


Figure 6: NO_X v/s BMEP with different biodiesel blends

2) Carbon Monoxide (CO) Emission

The CO emission from the diesel fuel with biodiesel blended fuels and biodiesel is shown in Figure 7. The CO reduction by biodiesel was 11, 10, 15 and 19 per cent at 2.9, 4.3, 5.6 and 6.6 kW load conditions. With diesel fuel mode the lowest CO was recorded as 360 ppm at 2.9 kW load and as load increased to 4.3 kW, CO also increased to 904 ppm. Similar results were obtained for biodiesel blended fuels and biodiesel with lower emission than diesel fuel. The amount of CO emission was lower in case of biodiesel blended fuels and biodiesel than diesel.

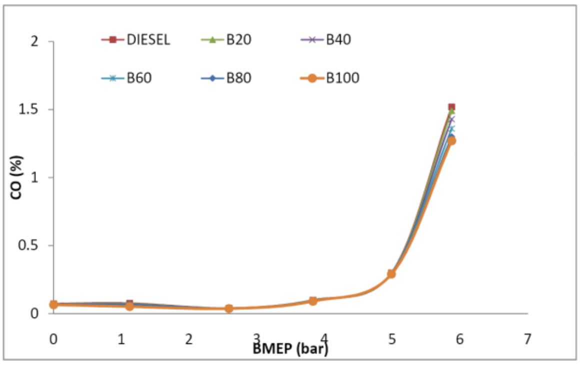


Figure 7: CO v/s BMEP with different biodiesel blends

3) Un-burnt Hydro Carbon Emissions

The un-burnt hydro carbon emission from the diesel engine with different blends is shown in Figure. 4. The HC emissions increased with increase in load conditions for diesel and for biodiesel blended fuels. The jatropha biodiesel followed the same trend of HC emission, which was lower than in case of diesel. The HC in the exhaust gas was decreased gradually with increased biodiesel proportion.

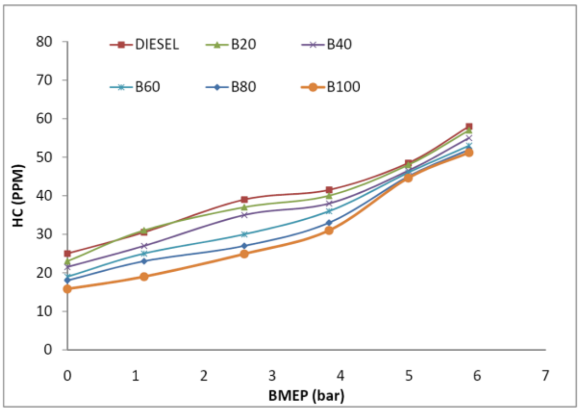


Figure 8: HC v/s BMEP with different biodiesel blends

4) Smoke Opacity

The smoke opacity from the diesel fuel with biodiesel blended fuels and biodiesel is shown in Figure 9. The smoke opacity reduction by biodiesel was 14, 15, 18 and 21 per cent at 2.9, 4.3, 5.6 and 6.6 kW load conditions. The Smoke opacity found to be decrease with increased biodiesel rate in fuel and it is seen that at full biodiesel fuel there was lowest smoke opacity.

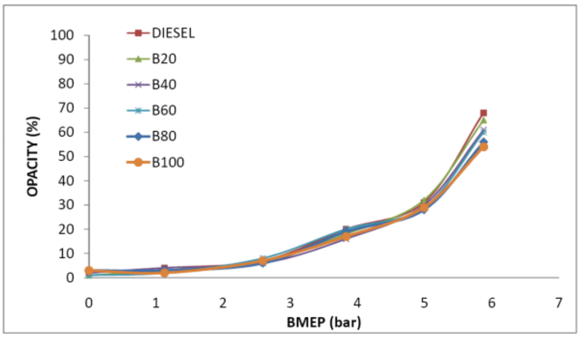


Figure 9: Opacity v/s BMEP with different biodiesel blends

V: CONCLUSIONS

In this experimental work Emissions like NO_X, CO, HC and smoke opacity were measured. Engine performance parameters such as brake thermal efficiency (BTE), brake specific energy consumption (BSEC) and exhaust gas temperature were also calculated. Results indicated that B20 have closer performance to diesel. The brake thermal efficiency for bio-diesel fuelled engine was slightly higher than diesel fuelled engine. There was increase in specific energy consumption and exhaust gas temperature with increase in bio diesel proportion in biodiesel blends. The rate of NO_X emissions from biodiesel was gradually increased by 15, 18, 16 and 11 per cent higher than that of the diesel at 2.58, 3.83, 4.99 and 5.88 BMEP (2.9, 4.3, 5.6 and 6.6 kW) conditions respectively. The carbon monoxide reduction by biodiesel was 11, 10, 15 and 19 per cent at 2.58, 3.83, 4.99 and 5.88 BMEP (2.9, 4.3, 5.6 and 6.6 kW) load conditions. Hydrocarbon (HC) and smoke opacity from the biodiesel and its blends was found lower than diesel fuel during the whole experimental range. Exhaust gas temperature increased with increase in load and amount of biodiesel. The highest exhaust gas temperature was observed as 455ºC for biodiesel among the four load conditions. The diesel mode exhaust gas temperature was observed as 368ºC.

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