ANALYSIS OF PERFORMANCE AND EMISSION CHARACTERISTICS OF A DIESEL ENGINE FUELLED WITH BIODIESEL

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Abstract: *The rapid depletion in world petroleum reserves and uncertainty in petroleum supply due to political and economical reasons along with the sharp escalation in the petroleum prices have simulated the search for alternatives to petroleum based fuels especially diesel and gasoline. Moreover, bulks of petroleum fuels are being consumed by agriculture and transport sector for which diesel engine happens to be the prime mover. Though there are wide varieties of alternative fuels available the research has not yet provided the right renewable fuel to replace diesel. Vegetable oil due to their properties being close to diesel fuel may be a promising alternative for diesel engines. Due to their high viscosity, they cannot be directly used in a diesel engine. Transesterification is one method by which viscosity could be drastically reduced and the fuel could be adopted for use in diesel engine. Present investigation focuses on use of Rice Bran Oil in Diesel engine. Performance and exhaust emission characteristics of the engine have been evaluated. Esterified Rice Bran Oil has exhibited performance very close to that of diesel fuel. In the present work it is observed that, the* NO_X *and unburned hydrocarbon emission decreases and carbon monoxide, particulate emission and smoke intensity increases with the use of biodiesel in diesel engine. When compared to non-esterified Rice Bran Oil, esterified Rice Bran Oil emits less smoke and therefore be regarded as an environment friendly fuel.*

INTRODUCTION

Efficient use of natural resources is one of the fundamental requirements for any country to become self sustainable. Both in organized and unorganized sectors Internal Combustion Engine has become an indispensable prime mover. Fast depletion of fossil fuels is demanding an urgent need to carry out research to find viable alternative fuels. Thermodynamic tests based on engine performance evaluations have established the feasibility of using a variety of alternative fuels such as hydrogen, CNG, alcohols, biogas, producer gas and a host of vegetable oils. To increase foreign exchequers and contribute towards protection of earth from the threat of environmental degradation, biofuels can be a good alternative for diesel in most of the developing countries. The fuels of bioorigin may be alcohols, edible and non-edible vegetable oils, biomass, biogas etc., Some of these fuels can be used directly while others need to be formulated to bring the relevant properties close to conventional fuels.

Vegetable Oils

Vegetable oil based fuels can be utilised as diesel alternatives for Diesel engines. Research work has revealed that the use of untreated vegetable oils in diesel engines has created problems such as injector fouling, lubricating oil dilution and other kinds of troubles. Vegetable oils are a mixture of organic compounds ranging from simple straight chain compounds to complex structure of proteins and fat soluble vitamins. Some inorganic compounds of heavy metals are also present. Vegetable oils have perceptible amount of nitrogen and sulphur which may affect emission spectra. Most of them are not only simple aromats containing hydrogen and carbon but also belong to the turbine class.

The chain length of fatty acids is inversely proportional to the thermal efficiency except at very small chain length. Proportion and the location of double bonds also affect the cetane number. On a volume basis, heat content of vegetable oils is almost comparable to diesel oil owing to greater densities it has. Heat value decreases with increasing unsaturation as a result of fewer hydrogen atoms and decreases with increasing saponification number.

Vegetable oils have the following advantages over diesel oil:

1. They are easily handled liquid fuels with properties close to those of diesel oil in many respects
2. They are a renewable source of energy.
3. They mix easily with diesel oil. Hence they can be used in the blended form also.
4. They can be produced in rural areas by well known agriculture practices. The extraction of the oil from the plant seeds is a relatively simple process which can also be carried out in rural areas.
5. Vegetable oils cannot be a substitute for petrol because of their high viscosity and poor volatility.

Some of the vegetable oil properties are given in the Table 1.1.

Problems with vegetable oils:

The problems encountered during engine tests with vegetable oils were studied and classified into two groups.

1. Operation Problems
2. Durability Problems

The operation problems were carbon deposits on injector, carbon deposits on piston and rings and also gum formation.

In order to reduce viscosity of vegetable oils, heating of oils has been tried out. Heating the oils however, transfers its spray characteristics more like diesel oil. Conversion of the vegetable oil to the simple esters of methyl and ethyl alcohols is called as biodiesel (ester) and it is a possible way to overcome almost all the problems associated with the vegetable oils, including the crank case polymerization problems.

Effect of injection pressure has been investigated to use of vegetable oil in diesel engine and concluded that this injection pressure could improve the performance and suggested that the endurance testing of the engine was essential with regards to the checking of gum formation in the combustion chamber.

Table 1.1: Fuel Properties of Vegetable Oil

Sl. No.	Vegetable Oil	Viscosity at 38°C mm²/C	Cetane No.	Calorific Value KJ/Kg	Density Kg/L	Flash Point °C	Cloud Point °C	Pour Point °C	Carbon Residue % Wt.
1.	Castor	29.7	42.3	37274	0.9537	260	-	-31.7	0.22
2.	Corn	34.9	37.6	39500	0.9095	277	-1.1	-40.0	0.24
3.	Cotton Seed	35.5	41.8	39468	0.9148	234	1.7	-15.0	0.24
4.	Crambe	53.6	44.6	40482	0.9044	274	10.0	-12.2	0.23
5.	Linseed	27.2	34.6	39307	0.9236	241	1.7	-15.0	0.22
6.	Peanut	39.6	41.8	39782	0.9026	241	12.8	-6.7	0.24
7.	Rapeseed	37.0	37.6	39709	0.9115	246	-3.9	-31.7	0.30
8.	Safflower	31.3	41.3	39519	0.9144	260	18.3	-6.7	0.25
9.	H.O. Safflower	41.2	49.2	39516	0.9021	293	-12.2	-20.6	0.24
10.	Sesame	35.5	40.2	39349	0.9133	260	-3.9	-9.4	0.25
11.	Soyabean	32.6	37.9	39623	0.9138	254	-3.9	-12.2	0.27
12.	Sunflower	33.9	37.1	39575	0.9161	274	7.2	-15.0	0.23
13.	#2 Diesel	2.7	47	43000	0.8400	52	-15.0	-33.0	20.35

Bio-diesel

Vegetable oil is converted into glycerol and ester of vegetable oil by method of Transesterification. This vegetable ester is also called as 'Biodiesel'. Its viscosity is drastically reduced when compared with vegetable oil and its properties come down comparable with diesel. In this present work Rice Bran Oil Ester (Biodiesel) has been taken and used as fuel in diesel engine.

Transesterification

Ethyl esters of vegetable oils were obtained by Transesterification and found that viscosities of esters were less when compared to pure vegetable oils and hence the engine has performed better with little higher smoke emissions. It is suggested that optimized injection timing could reduce the smoke emissions for esters.

Preparation of esterified vegetable oil was reported and observed that esterification has the effect of increasing the volatility and decreasing the viscosity of the oil, making it close to the characteristics of diesel fuel. Use of linseed oil esters has been tried out in a Diesel Engine and was found that there was a substantial decrease in exhaust smoke density for lower concentrations of ester in blends and observed that the fuel itself acts as a lubricant and thus the chance of wearing out gets substantially reduced.

EXPERIMENTAL SET-UP

The experimental setup consists of an engine, hydraulic dynamometer, measuring equipments for emission like NOx analyzer, smoke meter, CO and HC analyzer, tachometer for speed measurement, Nickel- Chromium thermocouple for temperature measurement and noise level meter for noise measurement.

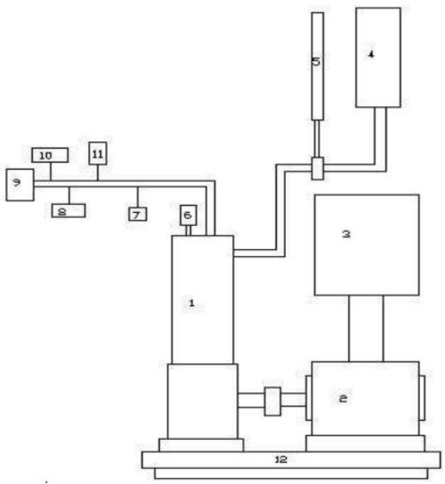

Figure 1. Schematic of the experimental set-up:

1. Test Engine 7. NO Analyser
2. Dynamometer 8.CO/HC Analyser
3. Dynamometer panel 9.Silencer
4. Fuel Tank 10.Exhaust Gas Temperature Indicator
5. Fuel Burette 11.Smoke
6. Air Filter 12.Engine Test Bed

Viscosity Reduction Techniques

High viscosity of vegetable oils has been reported by almost all researchers as the major bottleneck in their use as fuel. To overcome this problem, various techniques have been successfully tried and the advances in this area are summarised below.

Preheating

Since high viscosity is a major problem with vegetable oils, one possible solution is to heat the oils in order to reduce their viscosity or to heat the intake air in order to accelerate the evaporation of the vegetable oil in the engine.

In the present work, the engine was operated with 100ºC preheated fuel. The tested vegetable oil was heated by electrical power.

The oil viscosity was determined by using a redwood viscometer and density of the oil was calculated by a hydrometer.

Dilution

Dilution refers to mixing of vegetable oil with other low viscosity fuels like diesel, alcohol and others and it results in the reduction of the viscosity of the blends and in the increase of the cetane number.

Microemulsification

Microemulsification is a system consisting of a liquid dispersed in an immiscible liquid usually in droplets larger than colloidal size. The droplet size varying from 0.01 to 0.2 pm are generally considered as micro emulsions.

Micro emulsion conversion required no chemical reaction and tends to be rapid. These are transparent and thermodynamically stable colloidal dispersions. Micro emulsion formation depends upon interactions among molecules of constituents.

Transesterification

It is the process of reacting a triglyceride with ethyl alcohol in the presence of a catalyst like sodium hydroxide to produce glycerol and fatty acid esters. Temperature, catalyst type and concentration ratio of alcohol to fuel and stirring rate influences the esterification process to greater extent.

RESULTS AND DISCUSSION

The performance of the engine and emission parameters of the engine with Diesel, Raw Rice Bran Oil, Preheated Rice Bran Oil and Rice Bran Oil Ester (Biodiesel) are presented and discussed below. The performance characteristics of the engine are studied and compared with those obtained for the engine fitted with the particulate trap and with an ordinary muffler.

Brake Specific Fuel Consumption

The variation of brake specific fuel consumption with respect to brake power is shown in Fig. 10.1 The specific fuel consumption of Rice Bran Oil ester is 0.357 kg/kW hr. at full load condition and 0.334 kg/kW hr. for diesel. The specific fuel consumption of Rice Bran Oil Ester is higher compared to diesel but it is lower compared to Raw Rice Bran Oil and Preheated Rice Bran Oil. This is probably due to the low volatility, slightly higher viscosity and high density of the Rice Bran Oil Ester which affects mixture formation of the fuel and thus leads to slow combustion.

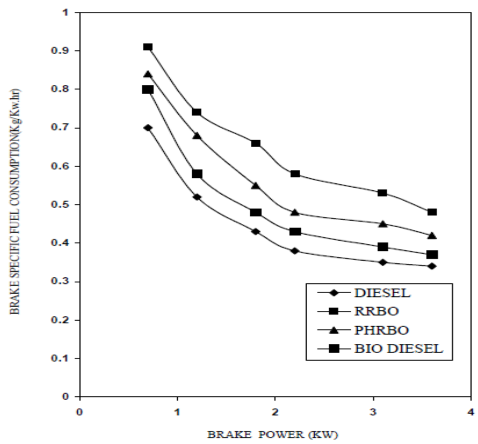

Figure 2. Variation of carbon monoxide emission with brake power

Brake Thermal Efficiency

The variation of brake thermal efficiency with respect to brake power is shown in 10.2. The brake thermal efficiency of Rice Bran Oil Ester is slightly lower compared to diesel operation. This is because of high viscosity, low volatility and high density of the ester which affects atomization of the fuel and thus leads to poor combustion. The maximum thermal efficiency of the Rice Bran Oil Ester is about 24.4%, where as it is 20.44% for diesel. The Brake Thermal Efficiency of Raw Rice Bran Oil and Preheated Rice Bran Oil are comparatively low with Rice Bran Oil Ester.

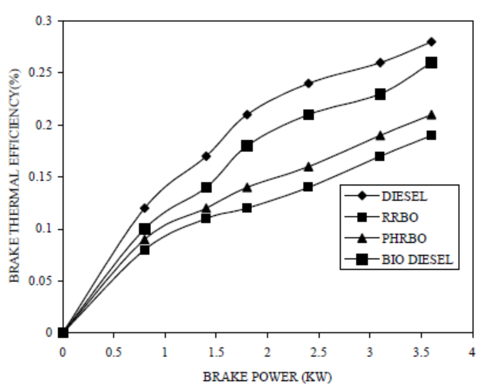

Figure 3. Variation of brake thermal efficiency with brake power

Exhaust Gas Temperature

The variation of exhaust gas temperature with respect to brake power is shown in Figure 10.3. Exhaust gas temperature is slightly higher when the load rises and it is higher for ester than diesel at high loads. However, exhaust gas temperature of the ester is lower compared to Raw Rice Bran Oil and Preheated Rice Bran Oil. Due to incomplete combustion of the injected fuel and part of combustion extending into the exhaust stroke there is a slight increase in exhaust gas temperature with Rice Bran Oil and its ester compared to diesel operation. The maximum temperature of exhaust gas at full load is 483°C for Rice Bran Oil Ester and 465°C for diesel.

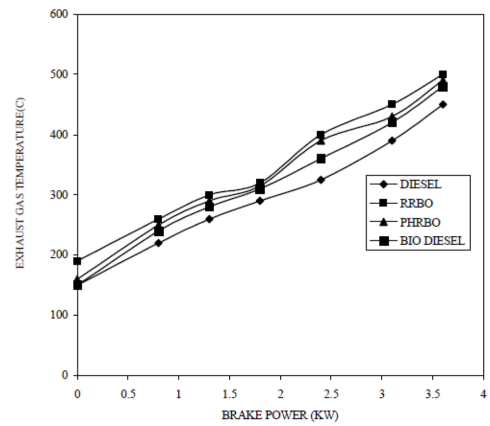

Figure 4. Variation of exhaust gas temperature with brake power

CO Emission

The variation of CO emission with respect to brake power is shown in Fig. 10.4. The CO emission of the Rice Bran Oil Ester is 0.62% volume at full load and 0.48% volume for diesel. The CO emission of Rice Bran Oil Ester is high compared to diesel operation. This is probably due to the use of richer mixture with ester due to lowered thermal efficiency. At the same time CO emission of Raw Rice Bran Oil and Preheated Rice Bran Oil is higher than ester.

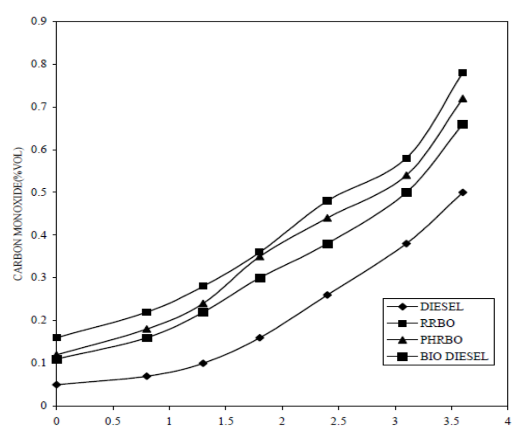

Figure 5. Variation of carbon monoxide emission with brake power

HC Emission

Fig. 10.5 shows the variation of HC emission with respect to Brake power. Unburned Hydrocarbon emission of Rice Bran Oil Ester is low compared to diesel and other fuels. At full load condition, HC emission is 75 ppm for Rice Bran Oil Ester and 125 ppm for diesel.

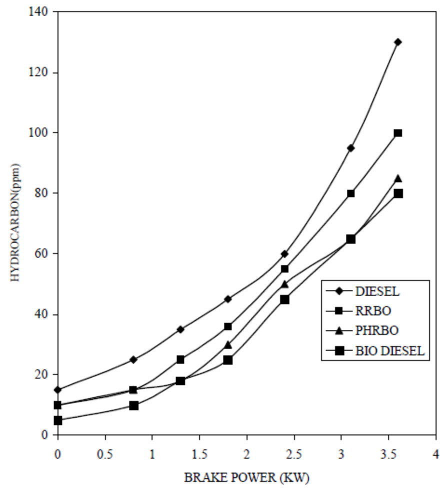

Figure 6. Variation of hydrocarbon emission with brake power

NOx Concentration

The variation of NOx concentration with respect to brake power is shown in Fig. 10.6. At full load condition NOx concentration is 330 ppm for biodiesel and 420 ppm for diesel. The NOx concentration of Rice Bran Oil Ester, Raw Rice Bran Oil and Preheated Rice Bran Oil are comparatively low to diesel operation. This is because Rice Bran Oil and its ester gives a lower peak pressure compared to diesel operation. Temperature is one of the major reasons for NOx formation.

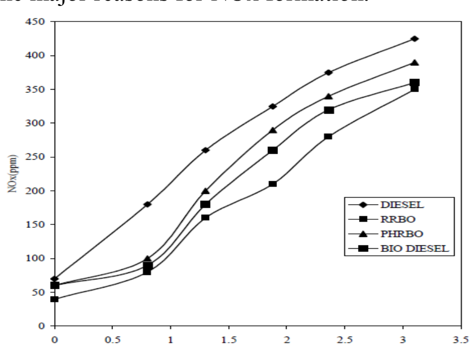

Figure 7. Variation of NOx concentration with brake power

Smoke Intensity

The variation of smoke intensity with respect to brake power is shown in Fig. 10.7. The smoke intensity of Rice Bran Oil Ester is 4.2 BSU at full load and 3.5 BSU for diesel. Rice Bran Oil Ester operation smoke intensity is increased at higher loads. This may be due to the higher viscosity and density of the ester that leads to poor vaporization and slow combustion of the injected fuel. When the highly viscous Rice Bran Oil is injected, the atomization of fuel is poor leading to larger droplets and less air entrainment resulting in inefficient combustion. This leads to higher smoke emission with Rice Bran Oil Ester. However, Raw Rice Bran Oil smoke intensity is higher compared to Rice Bran Oil Ester. This may be due to the higher viscosity and density of the Raw Rice Bran Oil.

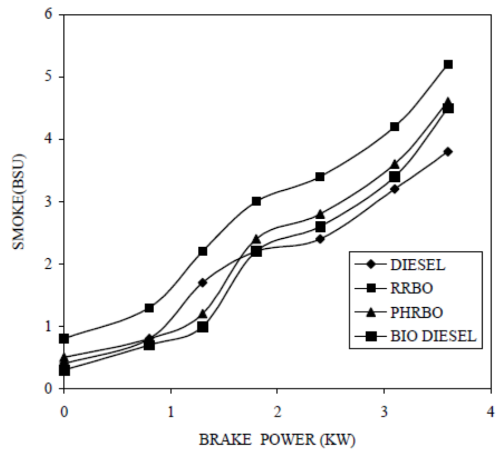

Figure 8. Variation of smoke intensity with brake power

Particulate Emission

The variation of particulate emission with brake power is shown in Fig. 10.8. The particulate emission of the Rice Bran Oil Ester is higher compared to diesel operation. This may be due to their incomplete combustion. At full load condition particulate emission is 5.36 g/hr for Rice Bran Oil and 4.52 g/hr for diesel.

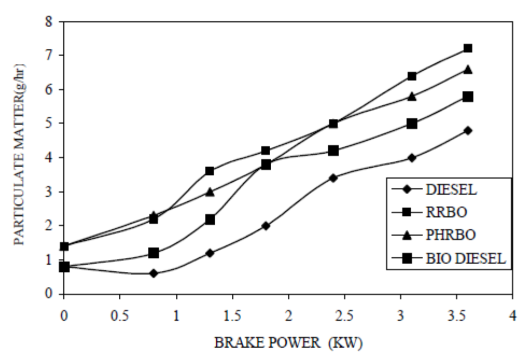

Figure 9. Variation of particulate emission with brake

CONCLUSIONS

Experiments were conducted on a single cylinder, water cooled DI diesel engine using Diesel, Raw Rice Bran Oil, Preheated Rice Bran Oil and Biodiesel (Rice Bran Oil Ester) and the following conclusions are made based on the experimental results.

- Engine works smoothly on biodiesel with performance comparable to diesel operation.
- Brake Specific Fuel Consumption of engine with biodiesel is increased by 6.44% from that of diesel.
- Break thermal efficiency of engine with biodiesel is reduced by 3.96% from that of diesel.
- The exhaust gas temperature with diesel is 465^{o}C and for biodiesel it is increased to 483^{o}C at full load conditions.
- Unburned hydrocarbon emission is significantly reduced with biodiesel. The percentage decrease in unburned hydrocarbon with biodiesel is 47% from that of diesel.
- Carbon monoxide emission with biodiesel is 0.62% by volume which is higher than that of diesel whose Carbon monoxide emission is 0.48% by volume. When compared to diesel, NO_x emission is reduced by 16.6% with biodiesel.
- The smoke emission of biodiesel is 15.3% higher than that of diesel.
- In particulate emission, the biodiesel is inferior to diesel, the emission increases by 14.3%.

Of the whole it is concluded that the Rice Bran Oil Ester (Biodiesel) will be a good alternative fuel for the diesel engine.

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