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Engine Performance and Emission Analysis of an IDI-Diesel Engine with Rice Bran Methyl Ester and Isopropanol Injection at Suction End

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Abstract:

The tail pipe emissions of petroleum diesel engines are considerably higher. In view of mandatory instructions from international pollution control board, the tail pipe emissions of the engines of automobiles should come down to lower levels. To comply with the pollution norms, the engines should use alternative fuels like biodiesel fuel and alcohols which have the capability to reduce the emissions from the engine. The choice of biodiesel is also a criterion to replace the petro diesel with the suggested one. In this present context the IDI engine is tested with the conventional petro-diesel and biodiesel along with biodiesel and several additive compositions. The additive used is Isopropanol (C₃H₈O) in various percentages viz. 2%, 3%, 4% and 5% of Isopropyl alcohol (additive) is injected calculated with reference to 1litre/hr. biodiesel and RBME is injected through the regular nozzle in a dual fuel mode. Isopropanol is injected into the air inlet at 3bar without suffering the volumetric efficiency. The main idea in introducing the additive is to dilute the combustion and thereby to reduce the combustion temperatures to limit the NO_x formation. Higher latent of isopropanol and volatility of the additive has its effect in reducing the combustion temperatures. From the investigation conducted 2% additive by volume has yielded encouraging results. Results envisage reduction of 2.63% & 3.12% at full load and proximate part load with respect to neat biodiesel. 4.3% & 4.9% hike in thermal efficiency at maximum load w.r.t diesel & biodiesel, 4.8% & 5.7% at part load as mentioned above is observed with the designated isopropanol percentage. HC reduction is observed as 5ppm at maximum load w.r.t diesel fuel. CO reduction is nearly 14% w.r.t diesel at maximum load. CO₂ has increased by 7.6% with respect to neat diesel. There is a reduction of 36.5% of NO with respect to diesel fuel. Reduction of 27.5 HSU is observed at Maximum load w.r.t diesel, even though, there is an increase in the smoke w.r.t biodiesel.

Abbreviations: HC- Hydrocarbon, CO-Carbon monoxide, CO₂-Carbondioxide, NO- Nitric Oxide, HSU- Hatridge smoke Units, RBME-Rice bran methyl ester, IP-Isopropanol.

Keywords: IDI-Engine, Rice Bran Methyl Estert, Isopropanol, electronic Injector.

1. Introduction

The use of vegetable oil in place of diesel fuel in conventional diesel engines requires modification in properties. Considerable efforts have already been made to develop vegetable oil derivatives that would approximate the properties and performance of the petro- diesel. The problem of substituting pure vegetable oils for diesel fuels is mostly associated with their high viscosities [1, 2]. Reduction of viscosity can be effected by any of the processes like transesterification, mineralization, preheating and pyrolysis. Mineralization consumes more time and pyrolysis brings about irregular molecular break down. Hence transesterification of vegetable oil is taken up in this work to experiment on a laboratory-based IDI engine with the dual fuel mode using rice bran methyl ester injection and isopropanol as secondary injected fuel at the air suction inlet at 3 bar pressure. IDI engine is preferred to ensure complete combustion and reduce crank case oil dilution which normally occurs in case of neat biodiesel application and thinner additive mixing.

Injection timings and quantities of additives like methyl and ethyl alcohols have affected the ignition delay and maximum pressure rise during combustion, [3].

The oxygenated alternative fuels such as methanol and ethanol have provided more oxygen during combustion. Therefore, the oxygenated alternative fuels and blends with gasoline and diesel fuel are more clean combustion processes than that of diesel and gasoline fuels [4-10]. The studies related to the alternative fuels should be enhanced for diesel engines especially for indirect injection (IDI) diesel engines. Because, they have a simple fuel injection system and lower injection pressure level. They do not

depend upon the fuel quality and have lower ignition delay (ID) and faster combustion than direct injection (DI) diesel engines. In this paper, simple isopropyl alcohol injection at air suction end at 3bar along with the usual Injection system for biodiesel with pintel nozzle is resorted to. The results obtained are appreciable with least modification of the engine almost keeping other parameters intact.

S. No	Name of the oil sample →	Diesel	Rice Bran Methyl Ester	Isopropanol
	↓Characteristics			
1	Density @ 33 ⁰ c (kg/m ³)	833	868.6	803.4
2	Lower calorific value (kJ/kg)	43000	38552	24040
3	Cetane number	51	63.8	4-10
4	Kinematic viscosity @ 33 ⁰ c (cSt)	2.58	3.57	1.7
5	Stoichiometric air – fuel ratio	15	13.8	9
6	Latent heat of evaporation (kJ/kg)	250	260	840
7	Flash point (⁰ c)	68	185	11.7
8	Fire point (⁰ c)	72	196	24

Table 1: Properties of the fuel used

2. Experimentation

Experiment is conducted on test rig consisting of IDI diesel engine (Bajaj RE100) in the Engines Laboratory of Department of Marine Engineering, Andhra University [Fig.1]. Iso-propanol (C₃H₈O) is injected at the suction end at a pressure of 3bar. The electronic injection system shown in [Fig.2] is controlled electronically and it is timed to inject after full suction valve opening. Assuming diesel consumption 1kg/hr at full load and the proportion of Isopropanol is calculated at the rate of 2%, 3%, 4% and 5%. The crank case oil dilution is regularly tested to verify the extent of contamination if any. Experimentation is carried out at various engine loads (Engine Loading device is eddy current dynamometer) combustion pressures are recorded to compute heat release rates with respect to the crank-angle. Exhaust gas analysis is taken up to compare the components of tail pipe emissions for various fuel additive compositions.

The experimental test rig consists of the following equipments:

- 1.Single cylinder engine loaded with eddy current dynamometer
- 2.Exhaust gas Analyzer
- 3.Smoke Analyzer
- 4. Electronic fuel injector

3. Experimentation Procedure

The experimentation is conducted on the engine operated at normal room temperatures of 280C to 330C in the Department of Marine Engineering, Andhra University. Dual fuel operation with Rice Bran Methyl Ester (RBME) and Iso propanol is taken up. Neat diesel oil is used at five discrete part load conditions to enable comparison. The data collection is done independently for the above said oils. The engine is run at 1500rpm continuously for one hour in order to achieve the thermal equilibrium under operating conditions. After this period, combustion pressure is monitored for every load on the engine. Fuel consumption is measured at each load.

Exhaust gas and smoke measurements are also made at different loads. The same procedure is repeated for the dual fuel operation with Isopropanol and RBME injection to compare the performance of the engine.



Figure1: IDI engine test rig facility

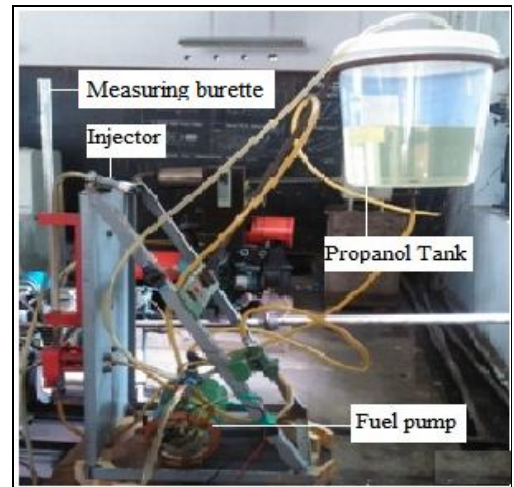


Figure: 2. Fuel tank, pump and electronic Injector system of isopropanol.

In-Direct injection (IDI) Diesel Engine, (Make BAJAJ company, Pune). The details of the engine are given table below:

Engine manufacturer	Bajaj RE Diesel Engine
Engine type	Four Stroke, Forced air and Oil Cooled
No. Cylinders	One
Bore	86.00mm
Stroke	77.00mm
Engine displacement	447.3cc
Compression ratio	24±1:1
Maximum net power	5.04 kw @ 3000 rpm
Maximum net torque	18.7 Nm @ 2200 rpm
Idling rpm	1250±150 rpm
Injection Timings	8.5 ⁰ to 9.5 ⁰ BTDC
Injector	Pintle
Injector Pressure	142 to 148 kg/cm ²
Fuel	High Speed Diesel
Starting	Electric Start

Table 2: Test engine Specifications

4. Engine Thermal Performance

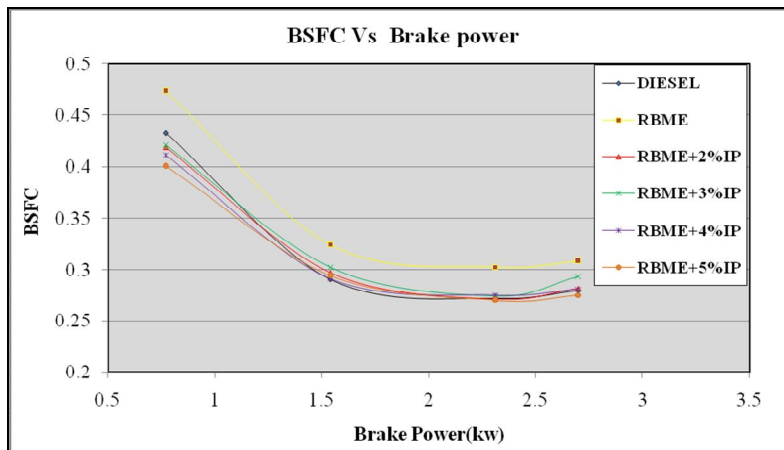


Figure 3: BSFC verses Brake power for all the fuel combinations

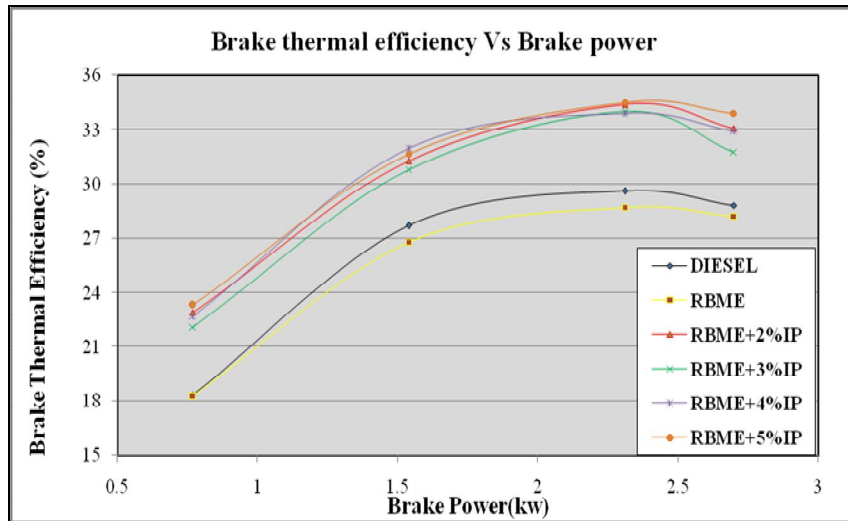


Figure 4: Brake Thermal Efficiency verses Brake power for all the fuel combinations

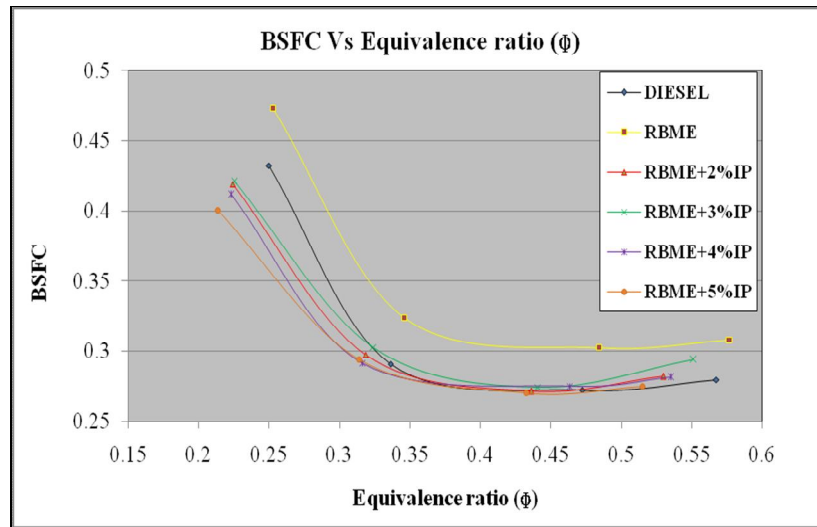


Figure 5: BSFC verses Equivalence Ratio for all the fuel combinations

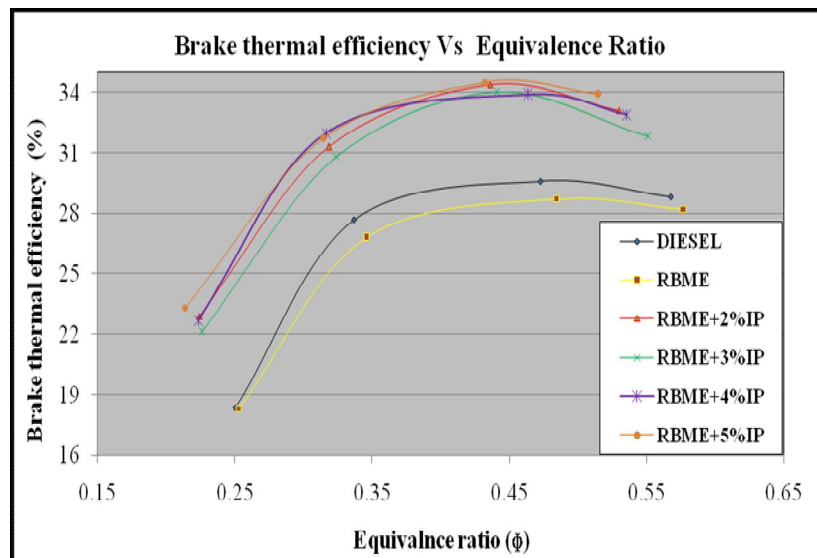


Figure 6: Brake thermal Efficiency verses Equivalence Ratio for all the fuel combinations

RBME with 2% isopropanol yielded best result in the context of brake specific fuel consumption and thermal efficiency as envisaged in the figures 3 & 4. Brake specific fuel consumption in case of 2% isopropanol additive in the biodiesel has decreased by 2.63% with the basic reference of biodiesel at 2.7kW load on the engine. At part load i.e. at 2.31kW, the BSFC has decreased by 3.12% for the same fuel samples as mentioned above. The Equivalence ratios have decreased by 4.73% & 4.81% respectively at maximum load and the part load mentioned above. Lower ‘ Φ ’ values of the engine indicate better performance of the engine at the mentioned loads by the use of 2% isopropanol and biodiesel combination. Even with respect to the petro-diesel, the performance of the 2% isopropanol in biodiesel has shown up in terms of equivalence ratio with the margin decrements by 3.78 % & 3.64% at the same mentioned loads above despite the reason that the lower calorific value of the diesel oil is comparatively more. There is a rise of Brake thermal efficiency by 4.3% & 4.9% at the maximum load and 4.8% and 5.7% at the part load mentioned with respect to diesel fuel and biodiesel respectively running the engine run with 2 percent isopropanol in biodiesel. It can be observed that isopropanol worked as a suitable additive at almost all percentages with better increase in thermal efficiency especially. Figures 3 to 6 envisage the above mentioned two aspects of engine performance depicting two aspects viz. Brake power and Engine equivalence ratio on abscissa separately.

5. Engine Emission Analysis

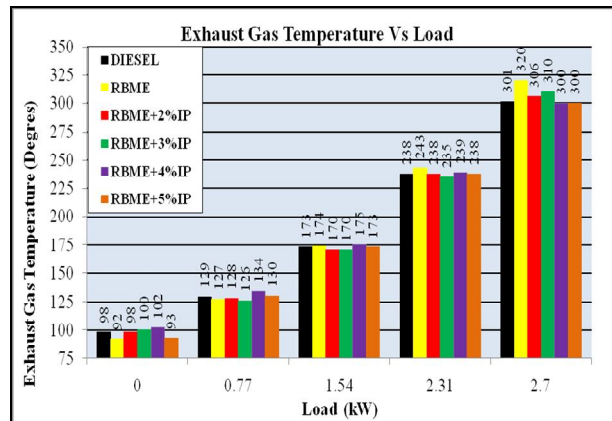


Figure 7: Pillar Plots of Engine exhaust temperatures with different fuel combinations.

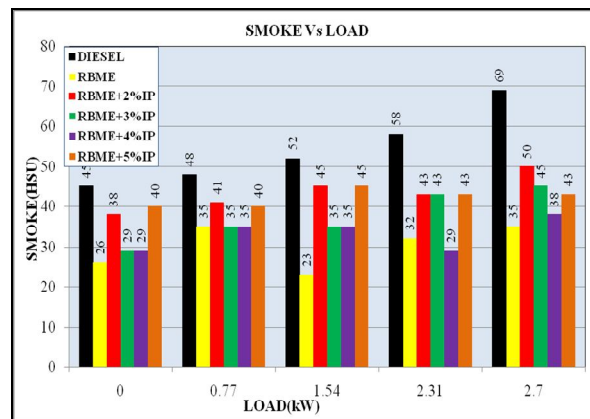


Figure 8: Engine smoke emission in Hatridge Smoke Units.

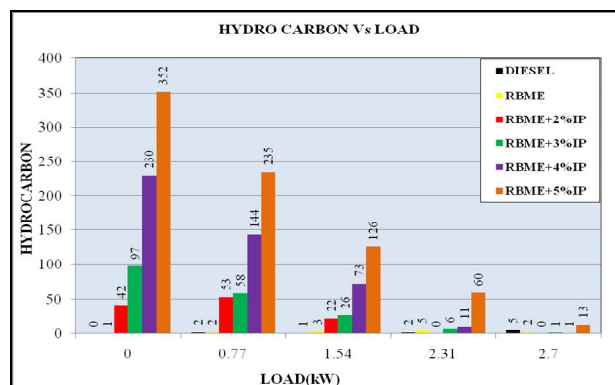


Figure 9: Hydrocarbon Emissions

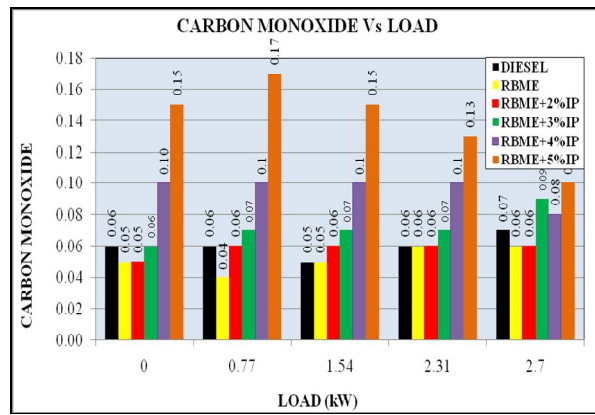


Figure 10: Carbon Monoxide Emissions

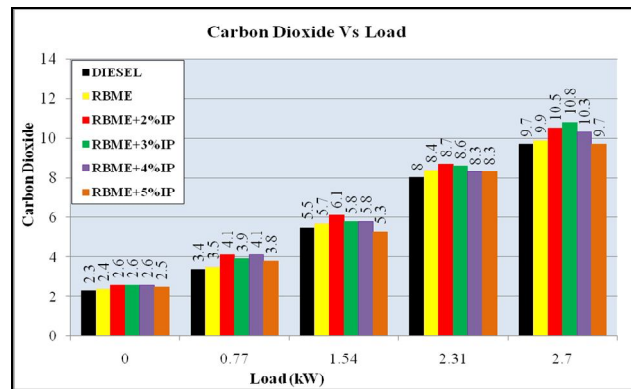


Figure 11: Carbon Dioxide Emissions

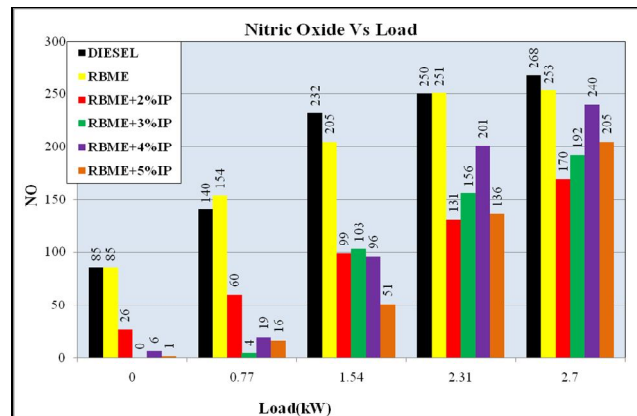


Figure 12: Nitric Oxide Emissions

Engine exhaust emissions viz. smoke, hydrocarbon, carbon monoxide, carbon dioxide, and Nitrogen Oxide have been depicted in the figures from 7 to 12. In the case of 2% isopropanol in biodiesel fuel usage in the engine, it is realized that except smoke emission, every emission has shown betterment even when compared to neat biodiesel which is known for its emission reduction over the conventional diesel fuel.

At immediate lower part load and maximum load on the engine, 2% isopropanol in biodiesel has shown exceptional hydrocarbon reduction and at lower loads there is an increase in HC emission. The trend of increase in HC has been very much identified with the increase of Isopropanol percentage in the biodiesel at lower loads on the engine. IDI engine normally has the efficiency in reducing the diesel emissions, especially, HC emission because of the combustion that takes place in two combustion chambers. The additive isopropanol has lower cetane number which is less than 10 and hence increasing its proportional quantity in biodiesel will increase the HC emission. Normally diesel engines have better part load efficiencies and advised to run at full load condition, and hence advantage is obtained with the 2% isopropanol additive.

Carbon monoxide levels are almost equal at all loads remaining at 0.06%. In the case of IDI engine, run with diesel and biodiesel this emission is particularly lower because of occurrence of total combustion of the fuel in both the combustion chambers. 2% isopropanol in biodiesel even proved more potential in reducing the CO emission and with the increase of isopropanol percentage this emission worsened still further increasing up to 0.17% at 5% isopropanol biodiesel combination which shows up an addition up to 0.11% over diesel fuel.

Carbon dioxide percentage has increased inconsonance with the additive percentage. This is because of the reason that isopropanol supplements excess oxygen embedded in its molecular structure. This is an additional source of Oxygen over the oxygenated biodiesel fuel.

NO emission decrease is appreciable in the case of 2% isopropanol in biodiesel and this is exceptional at maximum load running of the engine with a quantity decrement of 100ppm and 120ppm at immediate lower part load. This reduction is observed phenomenal at higher part load and full load of the engine. Of course, additive mixed fuels have shown up better performance because of low temperature combustion ensued due to higher latent heat of isopropanol. Because of relative higher isopropanol percentage at lower loads, the NO emission has further reduced.

It is an established fact that diesel fuel emits more smoke and biodiesel emits minimum smoke which is evident from the figure.8. Addition of isopropanol increases marginally the smoke because of low temperature combustion.

It is evident from the plot that any isopropanol addition is raising up the smoke levels by marginal extent. However, nearly 20 HSU decrease in smoke is observed at maximum load running of the engine with the implementation of 2% isopropanol in biodiesel.

6. Conclusions

The performance emission and combustion were evaluated.

Biodiesel with 2% Isopropanol injection is the efficient one in view of the engine performance, combustion performance and the emission aspects described in the results. The benefits are as follows.

- Smooth combustion pressure rise despite delayed peak Pressure.
- Smoother thermal efficiency rise and better performance at the highest load.
- Economical BSFC when compared to Neat bio diesel and petro diesel
- Lower exhaust gas temperatures at higher part loads indicating better torque conversion.
- Smoke level lesser than the petro diesel and Neat biodiesel.
- Reduced CO, HC levels in exhaust.
- NO emission decrease is appreciable and this exceptional at maximum load running of the engine.

Hence it is concluded that 2% isopropanol in biodiesel is suggested to be good replacement for the petro-diesel with the minor modification by introducing the additive injection equipment at the suction side.

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