

# Experimental investigation on emissions of direct injection diesel engine operating on dual fuel mode with Polanga based biodiesel and Ethanol

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## ABSTRACT:

In this research work ethyl alcohol is injected in combination with biodiesel fuel into the engine to decrease pollutants including smoke and NOx. Present research aimed at hardware development for introduction of ethanol in a direct injection diesel engine along with other fuel and to investigate emission characteristics. It talks on infrastructure, economics, and engine emissions etc. The use of biodiesel and ethanol in conventional direct injection diesel engines result in substantial decrease in NOx emission, carbon monoxide emission, carbon dioxide and particulate.

Key words: biodiesel; Emissions; Ethanol; dual fuel;

## 1. INTRODUCTION:

In the present work, an experimental investigation has been conducted to examine the effect of dual fuel combustion on the pollutant emissions of a Direct Injection Diesel engine. The engine has been properly modified to operate under dual fuel operation using Ethanol and diesel/biodiesel. However, use of ethanol as a fuel doesn't affect much in the case of petrol engine. Its use in CI engines creates problems, due to resistance to self-ignition, reason being very low cetane number etc.

Although diesel fuel cannot be entirely replaced by alcohols, its use with other fuel in different amount is becoming interesting for many researcher. No of techniques is being investigated for

injecting alcohols inside engine as a dual fuel injection system.

In this work alcohol is injected up to 30% with biodiesel in the engine. The objectives of the work are as follows:

- Investigation of application of ethyl alcohol injection in addition to biodiesel in dual fuel mode.
- Experimental Data analysis of emissions.

## 1.1 DUAL FUEL INJECTION:

Workman et al. [1] worked on the performance and emission of ethanol–diesel dual fuel CI engine. The thermal efficiency was increased

by the use of additional ethanol as a diesel fuel supplement, due to rise in volumetric efficiency with more air utilization, also increases ignition delay and the rate of pressure rise and peak pressure are reduced. The temperature of ethanol air mixture decreases with the injection of ethanol.

Many attempts to study dual fuel combustion have been made [11], [14], [15], [16]. These literatures have in common that the experiments are validated against small data sets and no decisions can be made regarding the validity over a wider range of engine conditions. Few of the models are validated for irrelevant operating conditions. Based on the above literature, it is concluded that dual fuel technology is not sufficiently understood to enable predictive modeling.

Andrzej K et al [20] compared duel fuelling (diesel and ethanol) with standard fuelling, (diesel fuel only) and showed more efficient and more friendly for environment. Higher overall efficiency is achieved by improvement of combustion

processes, lower hydrocarbon and CO emissions.

Chauhan B. S. [21] introduced ethanol with the help of constant volume carburetor in a small capacity diesel engine to study its effect on performance and emissions. Results suggested that the diesel engine gives better engine performance with lower NO<sub>x</sub>, CO, CO<sub>2</sub> and exhaust temperature. As per the parameters, the optimum percentage was found as 15% for ethanol.

Abu-Qadais M. [22] studied on both blend and injection of ethanol in the intake manifold and showed that there is improvement in performance and emission compared to blend. The optimum percentage of amount of ethanol injection is 20%.

## **2. Engine test set up.**

The Engine chosen to perform experiment is a single cylinder, four stroke, vertical, water cooled, direct injection computerized Kirloskar make CI Engine. The specifications of the engine given in Appendix and Fig. show the actual photos of the

C.I. Engine and its attachments. This DIC I diesel engine with online data acquisition system was used for investigation on emission

characteristics. The intake port system has been modified for Ethanol fuel injection.



Figure 1: Engine test setup

Sl. No.	Particulars	Specifications
1	Make	Kirloskar AV 1
2	Rated Brake Power (BHP/kW)	3.7KW /5 HP
3	Rated speed (rpm)	1500
4	Number of cylinder	One
5	Compression ratio	16.5:1

6	Cooling System	Water Cooled
7	Cubic Capacity	0.553
8	Bore x Stroke	80 x 110
9	Specific Fuel Consumption	185+5% gm/hp-hr

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### 3. Experimental Procedure:

The direct injection diesel engine got modified in dual fuel mode by connecting ethanol line to the intake manifold with injector. All the measurement equipment of all operating parameters and emission characteristics were fixed to the engine.

The water cooled piezo-electric pressure transducer connected to the amplifier is used to measure combustion pressure. The ethanol fuel flow rate is controlled by a digital multi-function microprocessor based fuel system. Data acquisition systems are used to process the important data and store in personal computer for offline analysis. The following parameters are fed in to the data acquisition system: density of fuel, calorific value, load on engine, and amount of ethanol to be injected additionally.

The test set up includes diesel engine along with one injector to inject ethanol, fitted to intake manifold, an Electronic control unit to control the

injection of ethanol, exhaust gas analyzer, smoke meter and data acquisition system fitted with various sensors. The entire experiment was conducted in following steps described below:

- The engine was switched on and allowed to run for 15-20 minutes to get stabilized. Initially, engine was run using the diesel fuel at all loads to determine the different engine characteristics and emissions. The engine being constant speed engine, the speed was maintained through out the entire engine operation at 1500 RPM.
- The same step was followed in dual fuel mode with changing the percentage of ethanol through a separate injection system. The percentage of ethanol taken was 10%, 20% and 30%. The ethanol injection was carried out at different crank angle to get the best result in terms of performance and emissions.
- Next the diesel oil in the engine and tank has been completely drained out. The filters were changed and biodiesel was filled in the tank. The engine was then run for some time to

make sure that the diesel phase is over and the engine has started working with biodiesel. Again all the engine operating parameters and emission characteristics are noted down at all the loads.

- After taking all the data for biodiesel the engine is tested in dual fuel mode with varying quantity of ethanol. All the data were recorded after the engine stabilized.

will affect the CO emission and can the same can be observed from the graph. At no load, CO decreases up to 20% of ethanol injection. At 50% load, there is an increase in CO% up to 20% of ethanol injection. At a load of 100% load, there is slight increase in CO till 20% ethanol and then surges fast with more ethanol injection.

## 4. Results and Discussion

### 4.1 CO emissions

Fig.2 (a), 2(b) show emission of CO in dual fuel direct injection compression ignition engine at no load, half load and full loads and at different percentage of ethanol. The air-fuel ratio decides the CO emissions. As per the experiment there is continuous increase in CO with increase in engine load. This is due to the reason, with increase of load the supply of diesel into the cylinder increases, air being same in the cylinder. It causes in additional quantity of diesel fuel provided into the engine. Quantity of air in the cylinder being same, as fuel injected has increased, combustion is partial and hence there will surge in emission of CO with load. With additional injection of ethanol, availability of some more oxygen

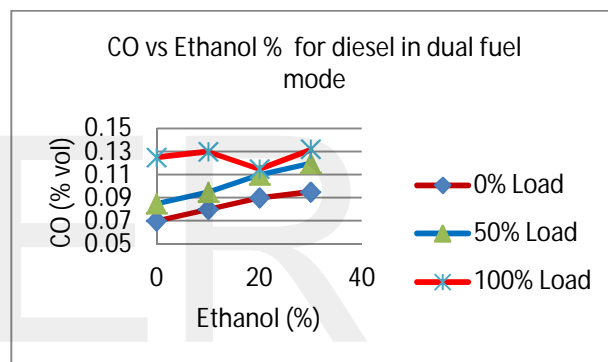


Figure 2(a) Emission of CO(%) with ethanol in dual fuel mode with diesel

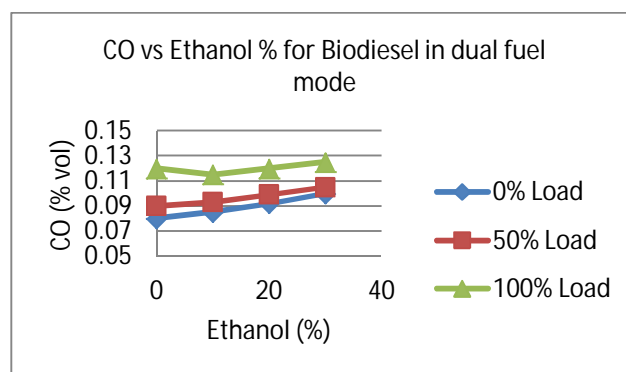


Figure 2(b) Emission of CO(%) with ethanol in dual fuel mode with biodiesel

## 4.2 CO<sub>2</sub> emissions

Fig. 3(a), 3(b) shows CO<sub>2</sub> emission of Dual fuel DI engine for different loading and ethanol percentage conditions. Mainly, CO<sub>2</sub> and water should be the product of petroleum combustion. As per the graph, at no load CO<sub>2</sub> emission is almost constant but when ethanol substitution

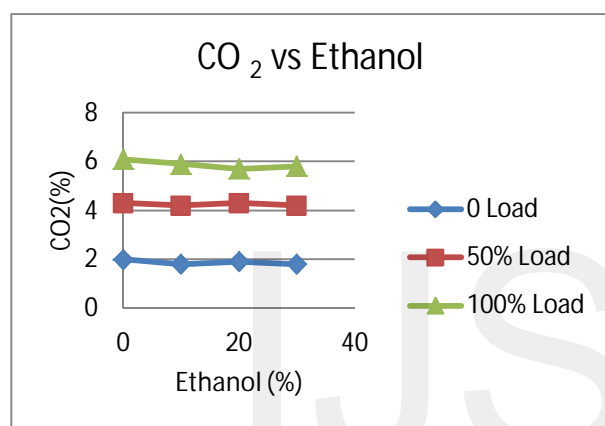


Figure 3(a) Emission of CO<sub>2</sub> (%) with ethanol in dual fuel mode with diesel

increased to 10%, 20% and 30% with higher load, CO<sub>2</sub> percentage decreases. At full load, CO<sub>2</sub> percentage decreases up to 10% substitution of ethanol. For graph, it can be observed that emission of CO<sub>2</sub> is minimum at 10% ethanol injection at full load.

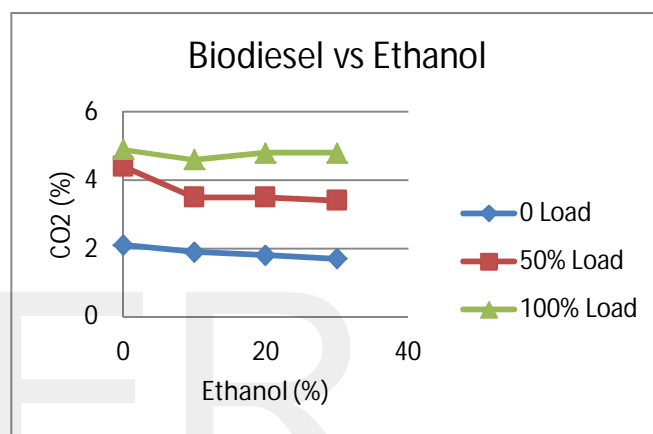


Figure 3(b) Emission of CO<sub>2</sub> (%) with ethanol in dual fuel mode with biodiesel

## 4.3 NO<sub>x</sub> emissions

The change in NO<sub>x</sub> emissions is shown in Fig 4 (a), 4(b) at 0%, 50% and 100% load conditions and at 10%, 20% and 30% ethanol injection. The emission of NO<sub>x</sub> is mainly dependent on the temperature inside the engine cylinder and the local air-fuel ratio of the mixture.

From the experiment It can easily be noticed that the NO<sub>x</sub> formation increased as the engine load increases, with increase in temperature due to load. It has been experimented that at zero load, NO<sub>x</sub> emissions reduce as we inject more amount of ethanol. At 50% load, NO<sub>x</sub> emission is minimum on 30% of ethanol but at 100% load, NO<sub>x</sub>

emission reduces up to 10% of ethanol substitution then keep increasing till 20% and again reduces

up to 30%. Ethanol injection decreases temperature inside the cylinder due to atomization.

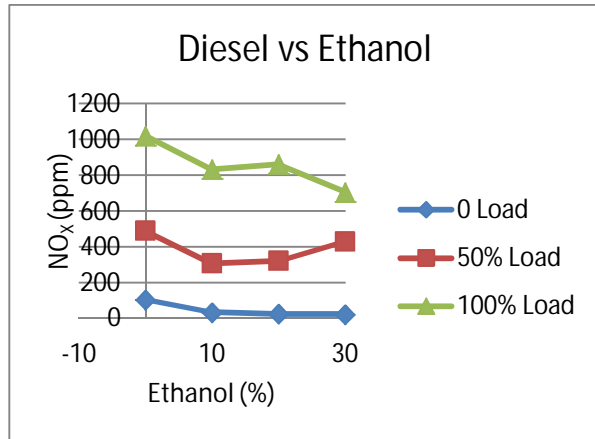


Figure 4(a) Emission of NO<sub>x</sub> (ppm) with ethanol in dual fuel mode with diesel

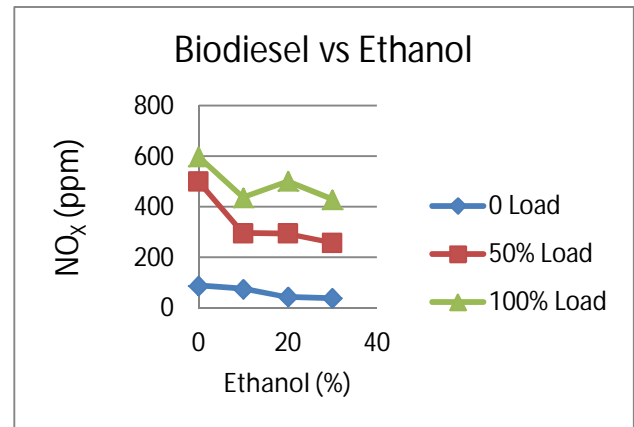


Figure 4(b) Emission of NO<sub>x</sub> (ppm) with ethanol in dual fuel mode with biodiesel

#### 4.4 Unburned HC emissions

The Graph of unburned hydrocarbon (HC) emissions is shown in Fig.5 (a), 5 (b) at 0%, 10%, 20% and 30% load conditions and at different rate of ethanol substitutions. At no and partial load conditions, the unburned HC emissions from the engine are more as the diesel/biodiesel is less apt to impinge on surfaces and because of poor fuel mixing, large quantity of excess air and less

exhaust temperature, lean fuel-air mixture regions may succeed to escape into the exhaust resulting higher HC emissions. It is found through experiment that at 50% and full loads, unburned HC gradually increases up to 10% ethanol substitution then remains constant and lowest for further ethanol injection due to better combustion at higher loads.

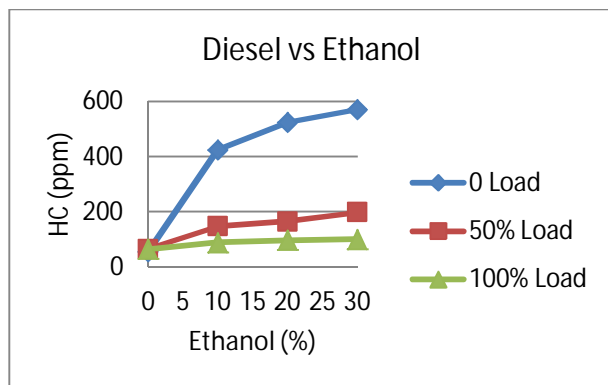


Figure 5(a) Emission of HC (ppm) with ethanol in dual fuel mode with diesel

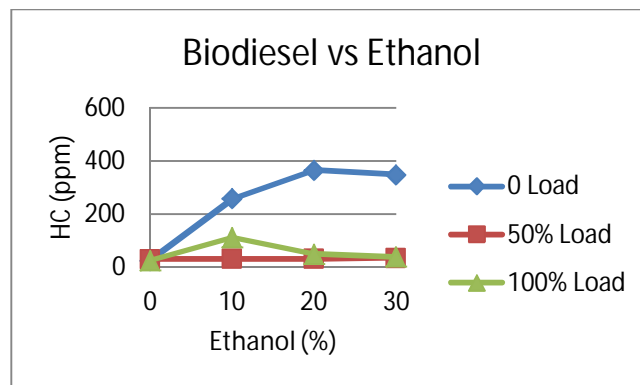


Figure 5(b) Emission of HC (ppm) with ethanol in dual fuel mode with biodiesel

From fig 5(b) below it can be observed that biodiesel gives relatively lower HC as compared to the neat diesel. The reason of better

combustion of biodiesel inside the combustion chamber is due to the availability of excess oxygen atom in biodiesel.

#### 4.5 Smoke Opacity

Fig. 6 (a), 6 (b) shows the variation of smoke opacity for different ethanol substitution at different load conditions. Smoke opacity defines as darkness of smoke due to carbon content blocks the light. For all load it was found that smoke opacity decreases as ethanol percentage increases. It can be seen from graph that slopes of ethanol injection decreasing and smoke opacity increases as we move towards high loads. At 100% load smoke opacity decreases sharply up to 10% ethanol. This is due to the fact that on ethanol substitution, oxygen content of

ethanol is responsible for better combustion and resulting into lower smoke opacity. At lower loads oxygenated excess air caused lower smoke opacity. At higher loads it increases due to improper mixing of ethanol and air mixture with Diesel fuel due to decrease in combustion time required for rich mixture. So it was found that for full load 30% ethanol injection gives minimum smoke opacity value. Restricted air filters, mismatch of injection timing, poorly maintained or malfunctioning engines are sometimes the cause of excessive smoke.



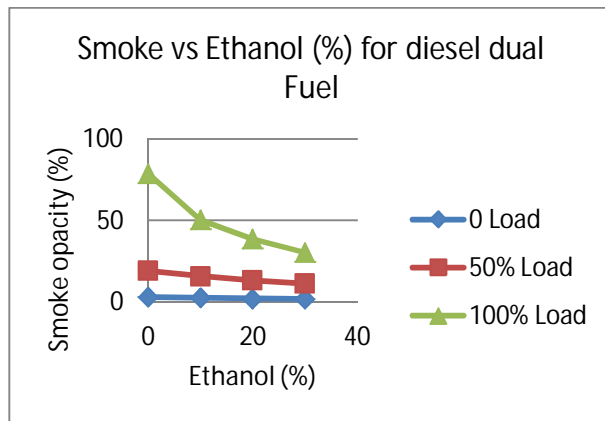


Figure 6(a) Emission of smoke (%) with ethanol in dual fuel mode with diesel

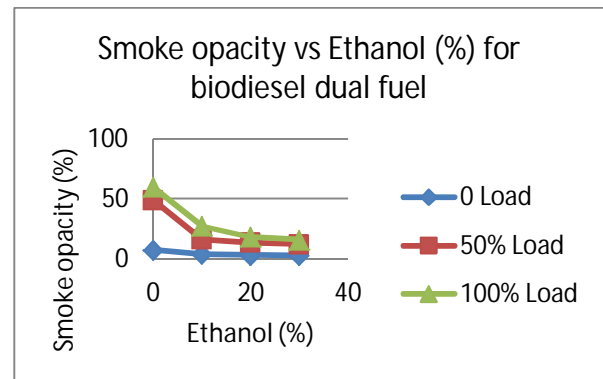


Figure 6(b) Emission of smoke (%) with ethanol in dual fuel mode with biodiesel

## 5. Conclusions

This work was undertaken to use Polanga based methyl ester with ethanol in dual fuel mode in Direct injection CI engine. This study compares the effects of injection of ethyl alcohol along with biodiesel in dual fuel mode. The conclusions which are drawn from this experimental study are as follows:

- In all cases, injection of ethanol in different percentage, and the use of above injection technique is good and gives reasonable results.
- Slight reduction in CO emissions up to 10% ethanol substitution and increase in HC emissions percentage were observed.

- Significant reduction in  $\text{NO}_x$  emission was observed at the injection of ethanol. Fast decrease in range of 30- 60 % can be seen in case of  $\text{NO}_x$ .  $\text{CO}_2$  remains almost constant at 0 load and at 10% and 30% load,  $\text{CO}_2$  percentage decreases as amount ethanol injection was amplified.
- It shows reduction of about 50% in engine smoke. This is because of the injection of ethanol in addition to main biodiesel, excess oxygen present in ethanol causes better combustion and results in lower smoke opacity.
- It needs least hardware changes in the engine, as alcohol is injected in the manifold with a simple system.

## 6. References

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