Performance and Emission Analysis of Compression Ignition Engine with Exhaust Gas Recirculation and Ethanol Fumigation

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Abstract

One of the undesirable emissions from diesel engine is NOx emission. In order to reduce NOx emission exhaust gas recirculation is used. Regulations to reduce NOx emissions continue to become more and more stringent year by year. Exhaust gas recirculation (EGR) is one of the techniques used to reduce nitrogen oxides because it lowers flame temperature in the combustion chamber. However as NOx reduces, hydrocarbon (HC) emissions and smoke level increases. As the EGR rate increases the engine operation becomes instable and there is a little reduction in thermal efficiency. Alcohol fumigation is a technique used for reducing emissions and improving the thermal efficiency of the engine. An experimental set up is fabricated to facilitate EGR and ethanol fumigation in the inlet duct of the engine. Engine performance, NOx and HC emissions without EGR, with EGR and with EGR and ethanol fumigation are presented in this work.

Keywords: Engine performance, EGR, ethanol fumigation, NOx, HC, emission

I. INTRODUCTION

Compression ignition (diesel) engines have high thermal efficiencies resulting from their high compression ratio and fuel lean operation. The high compression ratio produces the high temperature required to achieve auto ignition. During mixing of diesel fuel with air, different air-fuel ratios are formed. However high flame temperatures predominate because locally stoichiometric air-fuel ratios prevail in such heterogeneous combustion process. Consequently large amount of NOx are formed.

Some of the after treatment devices that reduces Nox emissions are, Diesel Oxidation Catalyst (DOC), Diesel Particulate Filter (DPF), Selective Catalytic Reduction (SCR) and NOX Storage Catalyst (NSC).

Instead of using after-treatment systems to comply with exhaust emission legislation, it is also possible to avoid the formation of emissions during the combustion. The raw emissions are reduced and thus no after-treatment is needed. It is common practice nowadays, to use EGR to reduce the formation of NOX emissions. A portion of the exhaust gas is re circulated into the combustion chambers. This can be achieved either internally with the proper valve timing, or externally with some kind of piping.

The exhaust gas acts as an inert gas in the combustion chamber, it does not participate in the combustion reaction. This leads to a reduction of the combustion temperature by different effects. The fuel molecules need more time to find oxygen molecule to react with, as there are inert molecules around. This slows down the combustion speed and thus reduces the peak combustion temperature, as the same amount of energy is released over a longer period of time. The energy is also used to heat up a larger gas portion than it would without EGR. As the air is diluted with exhaust gas, the mass of a gas portion containing the needed amount of oxygen gets bigger.

Another effect is the change in heat capacity. Exhaust gas has a higher specific heat capacity than air, due to the CO2-molecule's higher degree of freedom. So for the same amount of combustion energy a gas mass containing EGR will get a lower temperature than pure air. The lower combustion temperature directly reduces the NOX formation, as the NOX formation rate is highly temperature dependent.

One of the methods of utilizing ethanol in diesel engines is by means of fumigation, i.e., the introduction of ethanol into the intake manifold of a diesel engine. It is a form of dual-fuel operation where part of the fuel is premixed with the intake air, and part is injected into the cylinder as in a regular diesel engine. This injection of alcohol can be accomplished by means of a carburetor, atomizing nozzles, electronically-controlled fuel injectors, etc. Alcohol fumigation is a relatively simple and uncomplicated method which also features some important advantages: it can be made easily retro-fittable to existing engines and it easily allows the engine to switch back to neat diesel operation at any time. Unlike diesel-ethanol blends, miscibility does not pose a problem and in general, depending on several factors, the fumigation technique is able to replace up to about 50% of energy from diesel fuel.

II. EXPERIMENTAL SET UP

Experimental set up consists of the following three parts

A. Engine set up to measure load, rpm and fuel consumption which consists of eddy current dynamometer, control panel and burette.

Table – 1
CI Engine Specification

Engine	*Kirloskar tv1*
*Bore*stroke*	*87.5mm*110mm*
Cubic Capacity	*661 cm^3*
Compression Ratio:	*17.5:1*
Rated output:	*5.2kw at 1500 rpm*
Fuel injector pressure	*20-25Mpa*
Injection timing	*23 degree before TDC*
No of valves	*2*
Valve timing	*4.5 degree*
Inlet valve opens BTDC	*35.5 degree*
Inlet valve opens ABDC	*35.5 degree*
Exhaust valve opens BBDC	*4.5 degree*
Governor type	*mechanical ,centrifugal type*
Class of governing	*B1*
Fuel injection type	*Mechanical individual pump*

B. EGR and ethanol fumigation set up which is newly fabricated to facilitate EGR and ethanol fumigation which consists of orifice meter, manometer, burette, EGR flow control valve and ethanol flow control key. (Figure 2.1)

Fig. 2.1: Newly developed EGR and ethanol fumigation set up

1) Orifice meter

It is a device used for measuring the rate of flow of a fluid through a pipe. It is based on the principle of Bernoulli's equation. It consists of a flat circular plate which has a circular sharp edged hole called orifice, which is concentric with the pipe.

2) Manometer

It consists of 'U' tube attached to the two ends of orifice meter. It shows the head difference across the orifice meter. From the head difference volume flow rate is measured. The manometer limbs are filled with water.

3) EGR flow control valve

It is used to vary the flow of the exhaust gas into the inlet manifold of the engine

4) Ethanol flow control key

It is used to control the flow of ethanol into the inlet manifold of the engine

1) Emission measurement setup which consists of Five Gas Analyzer and Smoke meter.

III. RESULTS AND DISCUSSION

The following Figure3.1 shows the variation of thermal efficiency with brake power for 20%EGR with ethanol fumigation. EGR decreases thermal efficiency whereas ethanol fumigation increases the thermal efficiency. This is due to ignition delay which makes sudden release of heat so that no time is allowed for heat to be conducted to engine coolant.

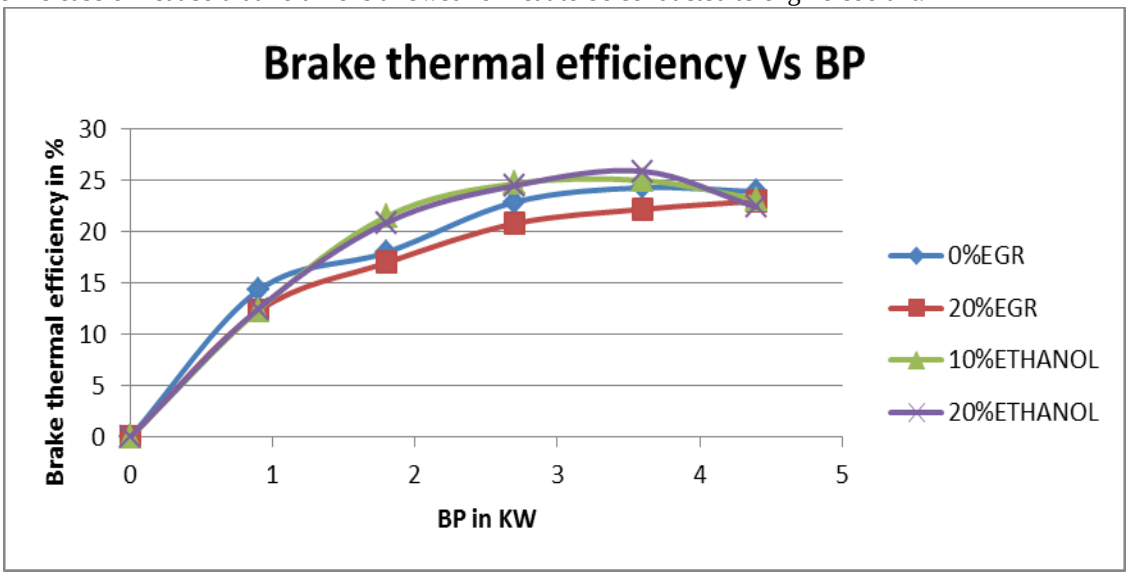

Fig. 3.1: Variation of thermal efficiency with BP for 20% EGR with ethanol fumigation

The following Figure3.2 shows variation of specific fuel consumption with brake power for 20% EGR with ethanol fumigation. Bsfc increases with EGR and decreases with ethanol fumigation. Ethanol is an additional source of fuel.

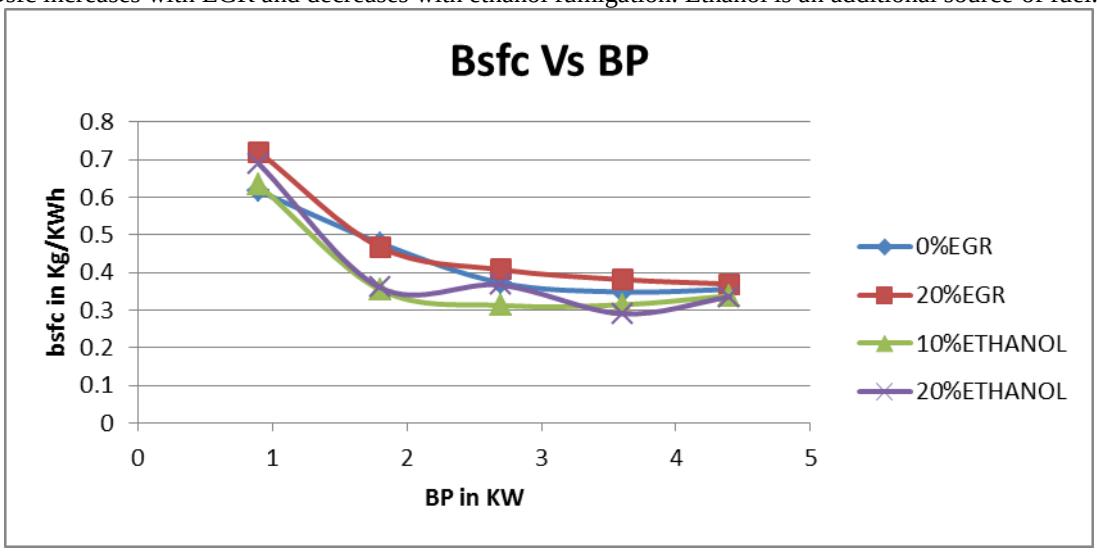

Fig. 3.2: Variation of bsfc with BP for 20% EGR with ethanol fumigation

The following Figure 3.3shows variation of NOx with brake power for 20% EGR with ethanol fumigation. NOx emission decreases with EGR and it further reduces with ethanol fumigation. It is due to dilution and cooling effect of alcohol in the combustion chamber.

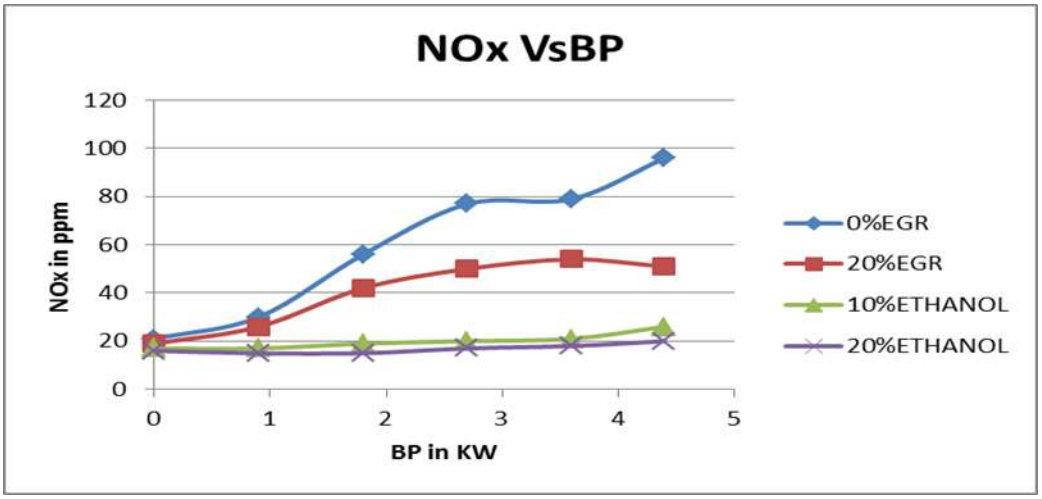

Fig. 3.3: Variation of NOx with BP for 20% EGR with ethanol fumigation

The following Figure3.4 shows variation of HC with brake power for 20% EGR with ethanol fumigation. HC increases with EGR and it greatly increases with ethanol fumigation. This is due to the fact that alcohol quench layer is formed and all the fumigated ethanol is not participating in combustion.

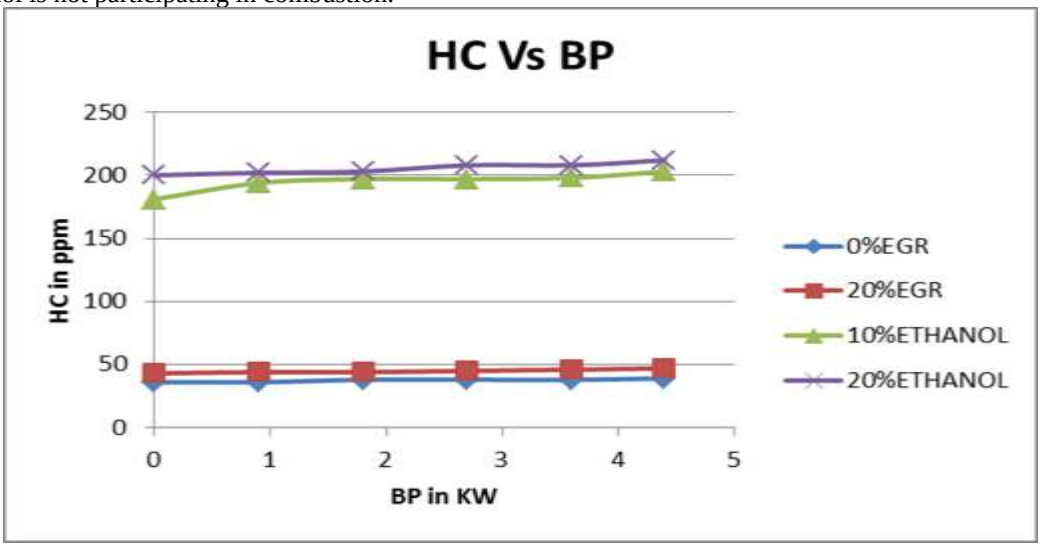

Fig. 3.4: Variation of HC with BP for 20% EGR with ethanol fumigation

The following Figure3.5 shows variation of smoke meter reading with brake power for 20%EGR with ethanol fumigation. Smoke opacity increases with EGR and it further increases with ethanol fumigation. This is due to the fact that some alcohols are escaping without participating in combustion.

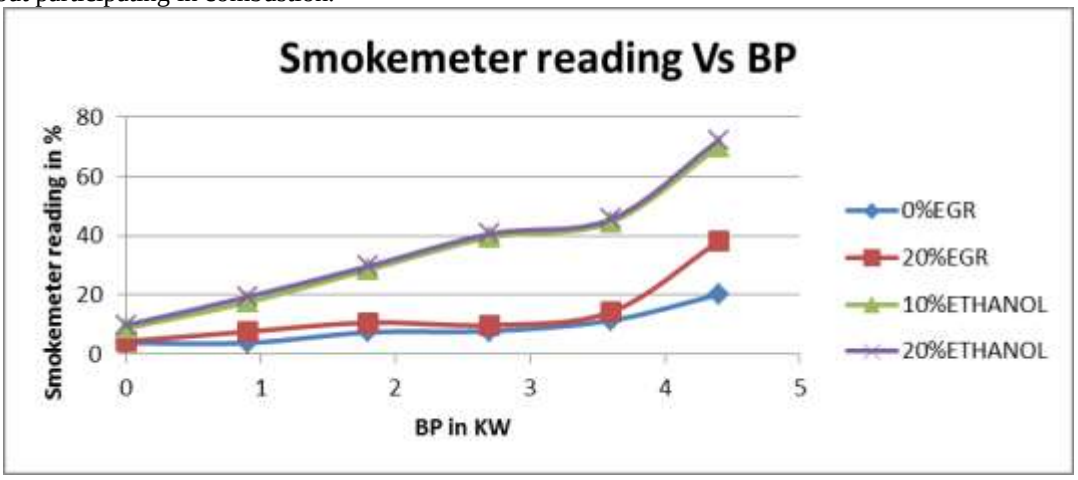

Fig. 3.5: Variation of smoke meter reading with BP for 20% EGR with ethanol fumigation

IV. CONCLUSION

- The present investigation is about fabrication of exhaust gas recirculation and ethanol fumigation set up and experimentation of various engine performance and emission with that set up.
- The following points can be concluded from the results obtained from the experiment.
- Thermal efficiency is decreased as the result of EGR. It increases with ethanol fumigation.
- Brake specific fuel consumption increases as EGR rate increases. But bsfc decreases with ethanol fumigation.
- EGR reduces NOx very effectively. When EGR rate is increased NOx is decreased accordingly. NOx formation further gets reduced with ethanol fumigation.
- HC emission increases with EGR. It increases significantly with ethanol fumigation.

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