A study of use of Cooled EGR on the performance and emission of the Diesel Engine

Nitin Shrivastava, Dr. S.N. Varma, Dr. Mukesh Pandey
Rajiv Gandhi Proudyogiki Vishwavidyalaya, Bhopal, India

***Abstract*— This paper discusses an experimental study conducted on an automotive Diesel engine in order to evaluate the effects of different rates of cooled Exhaust gas recirculation (EGR) on performance and pollutant emissions. The two different rates of 10 and 20 percent of EGR are used for the study. The performance parameters discussed are Brake specific fuel consumption (BSFC), Brake thermal efficiency (BTE). The Emission parameters discussed are carbon monoxide (CO), unburned Hydrocarbon (HC), Nitrogen oxides (NOx) and smoke. The results showed that the use of 10 and 20 percent of EGR reduces the average NOx emission by 20 and 32 percent respectively.**

Keywords- Diesel; performance; Emission; EGR

I. INTRODUCTION

With concerns about limited petroleum supplies and global warming driving the demand for fuel-efficient engines, interest Diesel engines are stronger than ever. Diesel engines are the most fuel-efficient engines ever developed for transportation purposes, due largely to their relatively high compression ratios and lack of throttling losses [1]. In light of the current requirements as regards the reduction of pollutant emissions of Diesel engines such as EURO 6 in Europe, manufacturers have to develop new in-cylinder strategies and/or after-treatment devices. With the upcoming pollutant emission regulations, nitrogen oxides (NOx) emissions will become particularly crucial on automotive Diesel engines. Hence there is a constant need to improve on existing strategies and also develop new methodologies for reduction of engine-out NOx [2, 3].

NOx constitutes of NO and NO_2. Both the gases are considered toxic, NO_2 is considered 5 time toxic than the NO. Formation of NO_2 is largely depends upon the oxidation of NO, so the attention has been given on how NO can be controlled before and after combustion [4].

NO is formed during the post flame combustion process in a high temperature region. The most commonly accepted mechanism was suggested by Zeldovich. The principal source of NO formation is the oxidation of the nitrogen present in the atmospheric air. The nitric oxide formation chain reactions are initiated by atomic oxygen, which forms from the dissociation of oxygen molecules at the high temperatures reached during the combustion process.

The different methods are available for the reduction of NOx. The cetane improvers are capable of reducing NOx but the addition of cetane improvers increase the cost of fuel and the possibilities of auto oxidation. Retarded injection is the method used for reduction in NOx for Compression ignition engines but the method leads to increase in Brake specific fuel consumption and emissions. Water injection leads to corrosion and increase in the weight due to water storage [5].

Exhaust gas recirculation (EGR) into the engine intake is the most used and studied technology as regards the in-cylinder strategies aiming at reducing NOx emissions. EGR involves the re-circulating the part of the tail pipe exhaust gases back into the cylinder. This results in the three different effects. First is the thermal effect which is related to the increase in the charge specific heat capacity due to the presence of CO_2 and hence the lower gas temperature rise in the combustion chamber. The second effect is the chemical effect which is related to the dissociation of species during combustion. And the third effect is the dilution effect which is related to the reduction in oxygen and Nitrogen availability due to the replacement of the fresh air by the CO_2 and water molecules.

The re-circulating the cooled EGR helps in reducing the inlet charge temperature especially at high load, which will rise the working fluid temperature. Cooling of EGR increases the intake charge density, volumetric efficiency and consequently resulting in higher oxygen content. This increase in available oxygen during combustion also helps in oxidation of soot. Test results reported higher NOx reduction with cooled [6].

In the present investigation two different rates of cooled EGR, 10 and 20 percent are used to compare the performance and emission parameter of a naturally aspirated diesel engine.

II. EXPERIMENTAL SETUP AND TEST PROCEDURE

The experimental setup shown in Figure 1 consists of a four cylinders, four stroke, direct injection diesel engine, an engine test bed with hydraulic dynamometer. The specifications of the test engine are given in Table 1. The test bed contains instruments for measuring various parameters such as engine load, air flow by anemometer, gas temperatures by K type thermocouples. The fuel consumption was determined by weighing the fuel on an electronic scale. For the analysis of the exhaust, Eurotron green line gas analyzer and AVL 437 smoke meter were used.

TABLE I. ENGINE SPECIFICATION

Make	Force motors
Cylinder Number and Type	Four and Four Stroke
Rated Power (H.P.)	27
Rated speed	2200 rpm.
Bore(mm)	78
Stroke(mm)	95
Compression Ratio	18.65:1

The exhaust gases coming out from the engine cylinder was partly re-circulated into the intake manifold by creating an external EGR pipeline. An EGR cooler was used to reduce the exhaust gas temperature using water, and a valve is placed in the EGR route to control the flow. An air damping box was placed in this route to compensate the pulsating nature of the exhaust gases. The gases before entering the cylinder were then passed to the particulate filter containing steel wool to reduce the particulates entering into the combustion chamber. The percentage of EGR is calculated based on the following equation.

EGR rate =100 X ($Q_{\text{without EGR}} - Q_{\text{EGR}}$) / $Q_{\text{without EGR}}$ %

Where $Q_{\text{without EGR}}$ is the air flow rate before EGR where as Q_{EGR} is the air flow rate using EGR.

The test was carried out at a constant rpm of 2000 and by varying the load and varying the percentage of EGR. The performance parameters tested was brake thermal efficiency, brake specific energy consumption, carbon monoxide, unburned hydrocarbon, NOx and smoke emissions.

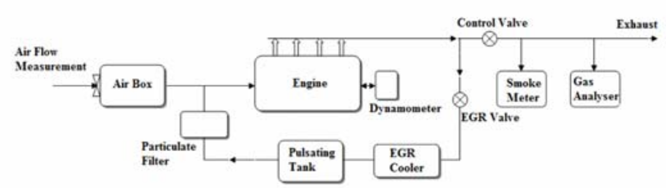

Figure 1. Experimental set up

III. RESULT AND DISCUSSION

A. Brake specific fuel consumption

Figure 2 shows the variations of the BSFC with the Brake mean effective Pressure (BMEP). The value of BSFC decreases with the increase in the load. The possible reason could be the reduction in losses at higher loads. Use of EGR showed almost same fuel consumption. The 10 and 20 percent of EGR showed an average 0.8 percent and 2.2 percent increased fuel consumption.

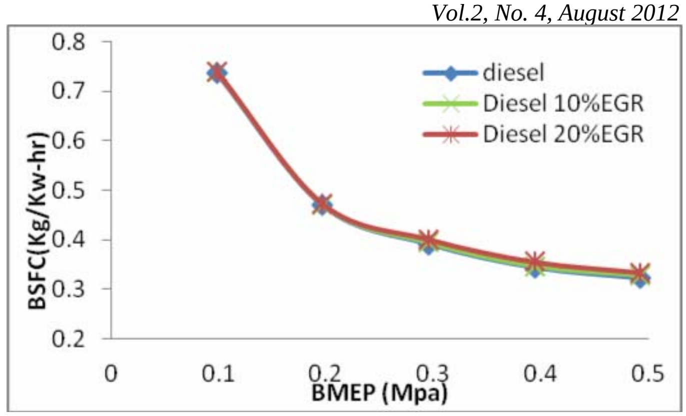

Figure 2. Variation of BSFC with the BMEP

B. Brake Thermal efficiency

Figure 3 showed the variations of the Brake thermal efficiency (BTE) with the BMEP. The value of BTE was increased with an increase in the load. The use of EGR showed almost same BTE. The Use of 10 percent and 20 percent of EGR showed an average 0.8 and 2.1 percent reduction in BTE. The possible reason could be reduction of the flame temperature due to diluents admission resulting in the reduction of brake thermal efficiency. Here it was observed that the higher rate of EGR showed a comparatively higher drop in thermal efficiency and especially at elevated load conditions.

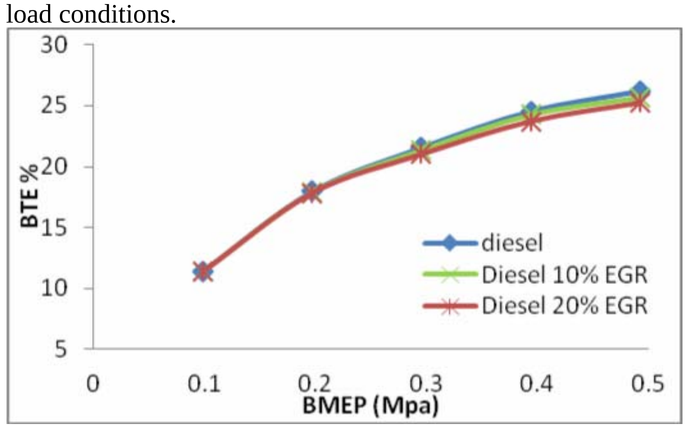

Figure 3. Variation of BTE with the BMEP

C. Carbon monoxide Emission

Figure 4 presented the variations of carbon monoxide (CO) Emission with the BMEP. It was observed that the CO emission was decreased with the increase in the load. This trend was different from the most of the researchers worked on different fuels on the Diesel Engine [7-10]. A similar trend was observed by few [11]. Use of EGR results in increased CO Emissions. The 10 and 20 percent of EGR showed an average 10.7 and 21.7 percent increased CO emission compared to without EGR. Increase of CO emission while using EGR may be due to the increase in fuel consumption reducing the air fuel ratio which in turn increases the CO Emission.

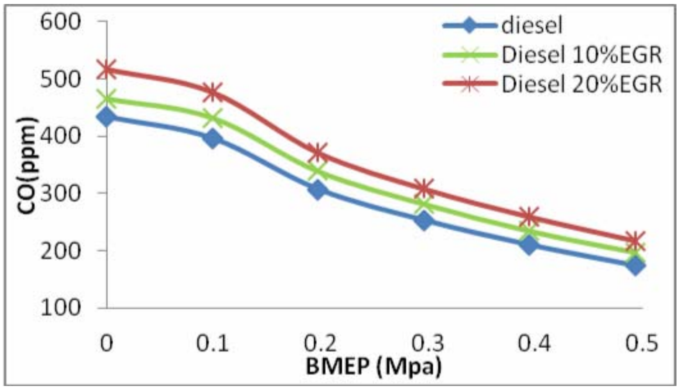

Figure 4. Variation of CO Emission with the BMEP

D. Unburned Hydrocarbon Emission

The variation of Hydrocarbon (HC) emission with the BMEP is presented in Figure 5. It can be observed that HC emission increases with the increase in load. The effect of EGR was more pronounced at higher loads. The EGR results in an average 16.6 and 43.9 percent increased HC Emission. The EGR rate of 20 percent showed drastic improvement in the HC emission. This could be due to lack of oxygen availability for the oxidation of fuel.

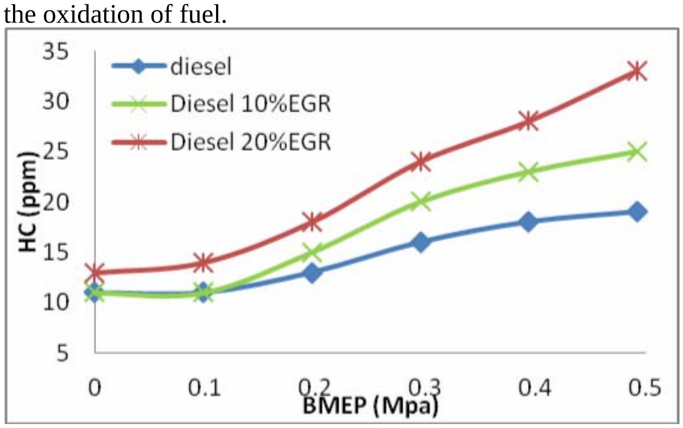

Figure 5. Variation of HC Emission with the BMEP

E. Nitrogen oxide Emission

Figure 6 showed the variations of the Nitrogen oxides (NOx) emission with the BMEP. It was observed that the EGR showed significant reduction in NOx emission especially at higher loads. The use of 10 and 20 percent of EGR showed an average 20 and 32 percent reduction in NOx emission compared to without EGR respectively. This reduction in NOx emission can be attributed to the lowering of the exhaust gas temperature by the diluents admission in the combustion chamber. However it was also observed that the use of higher EGR rate not showed effective reduction in NOx emission as compared to the lower EGR rate.

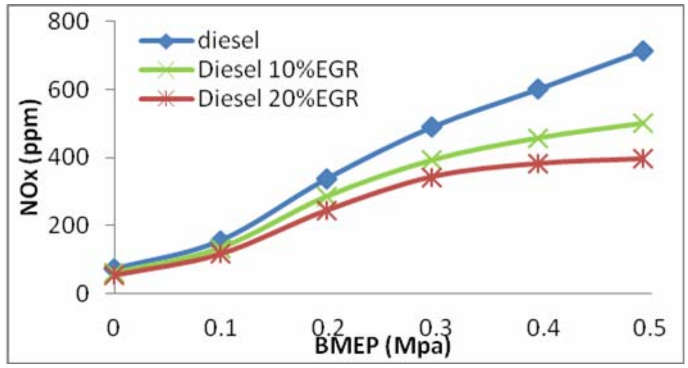

Figure 6. Variation of NOx Emission with the BMEP

F. Smoke Emission

Figure 7 shows the variations of smoke emission with the BMEP. The smoke emission increases with increase in load. The possible reason could be charge becomes more fuel rich at higher loads. The use of EGR results in increased smoke emission. The 10 and 20 percent of EGR showed an average 21.2 and 35.5 percent increased smoke emission. The reason could be reduced oxygen availability, in the combustion chamber to premix with the fuel injected, and to oxidize the formed soot.

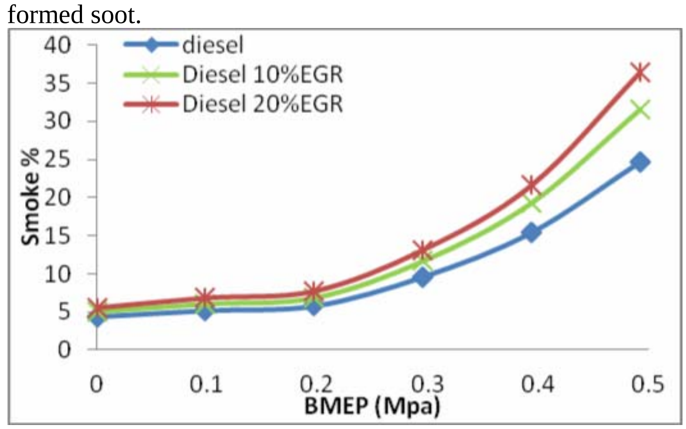

Figure 7. Variation of Smoke Emission with the BMEP

IV. CONCLUSION

The study was carried out to compare the performance and Emission parameters of a Diesel Engine using different EGR rate on the Diesel engine. The major conclusions of the study are as follows.

- The use of EGR is an effective method of reducing the NOx emission
- The EGR results in approximately same Brake thermal efficiency
- EGR results in slight penalty in CO, HC and smoke emissions.
- High rate of EGR showed higher smoke emission and was not found to be as effective as compared to the low rate of EGR.

References

[1] J. E. Dec, "Advanced compression-ignition engines understanding the in-cylinder processes," Proceedings of the Combustion Institute, vol. 32, pp. 2727–2742, 2009.

[2] W. Knetch, "Diesel engine development in view of reduced emissions standards," Energy, vol.33, pp.264-271, 2008.

[3] X. Tauzia, A. Maiboom, S.R. Shah, "Experimental study of inlet manifold water injection on combustion and emissions of an automotive direct injection Diesel engine," Energy, vol. 35, pp.3628-3639, 2010.

[4] Y.A. Levendis, I. Pavalatos, R.F. Abrams, "Control of diesel soot hydrocarbon and NOx emissions with a particular trap," SAE Paper 940460, 1994.

[5] V. Pradeep, R.P.Ã. Sharma, "Use of HOT EGR for NOx control in a compression ignition engine fuelled with bio-diesel from Jatropha oil," Renewable Energy, vol. 32, pp.1136-1154, 2007.

[6] N. Abu-Hamdeh, "Effect of cooling the recirculated exhaust gases on diesel engine emissions," Energy Conversion and Management, vol. 44, pp.3113-3124, 2003.

[7] B. Baiju, M.K. Naik, L.M. Das, "A comparative evaluation of compression ignition engine characteristics using methyl and ethyl esters of Karanja oil," Renewable Energy, vol. 34, pp.1616-1621, 2009.

[8] G. Sharanappa, C. H. S. Murthy, R. P. Reddy, "6BTA 5.9G2-1 Cummins engine performance and emission tests using methyl ester mahua (Madhuca indica) oil/diesel blends," Renewable Energy, vol. 34, pp. 2172-2177, 2009.

[9] G. Sharanappa, Ch. S. Murthy, R. P. Reddy, "Performance and emission characteristics of a Kirloskar HA394 diesel engine operated on fish oil methyl esters," Renewable Energy, vol. 35, pp. 355-359, 2010.

[10] A.S. Ramadhas, C. Muraleedharan, S. Jayaraj, "Performance and emission evaluation of a diesel engine fueled with methyl esters of rubber seed oil," Renewable Energy, vol. 30, pp.1789-1800, 2005.

[11] M. Mani, G. Nagarajan, S. Sampath, "An experimental investigation on a DI diesel engine using waste plastic oil with exhaust gas recirculation," Fuel, vol. 89, pp.1826-1832, 2010.