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# Effect of Exhaust Gas Recirculation (EGR) On Engine Performance and Emission on C I Engine

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**ABSTRACT**

An internal combustion engine is having a high efficiency, high power with lower maintenance cost. Because of that Internal Combustion Engines are increased worldwide. It is the main power source for the automobile vehicles. Now a present emission norm becomes strict for any I.C. Engine. The main pollutant are CO, CO2, HC, NOx, PM, soot, etc from which NOx are one of the most harmful component. It affects the human and other living organisms. It is possible to limit the NOx in the atmosphere by various methods like exhaust gas recirculation (EGR), catalyst or SCR and water injection. The aim of this work is to find the effect of exhaust gas recirculation (EGR) to reduce the NOx emission from the I. C. Engine with measuring the all pollutants for different EGR with different load condition and find the optimum condition of emission and performance. It is found that adding EGR to the fresh air it is beneficial to reduce the NOx emission. Reductions in NOx emission are achieved by previous research with 5% to 30% EGR. However, EGR has other effects on combustion and emission production that are increase of intake charge temperature, delay in heat release, decrease of peak cylinder temperature and decrease in $O_2$ concentration in cylinder charge and decrease the air-fuel ratio.

***Keywords*** - Diesel Engine, EGR, CO, HC, NOx, PM, Soot.

## 1. INTRODUCTION

In internal combustion (IC) engines, exhaust gas recirculation (EGR) is a nitrogen oxide (NOx) emissions reduction technique used in petrol/gasoline and diesel engines. EGR works by re circulating a portion of an engine's exhaust gas back to the engine cylinders.

**Ladommatos N, R. Balian, et al. [1]** in this paper authors studied about the effects of exhaust gas recirculation on diesel combustion and emissions. The investigation was carried out on a high speed direct injection diesel engine running at an intermediate speed and load. It was found that very large reduction in exhaust NOx at the expense of higher particulate emission.

**Avinash Kumar Agarwal, Shravan Kumar Singh [2]** they conducted an experiment on a two-cylinder, direct injection, air-cooled CI engine to observe the effect of exhaust gas recirculation on the exhaust gas temperature and exhaust opacity. It is seen that exhaust gas temperature reduces drastically by employing EGR. Thermal efficiency and brake specific fuel consumption are not affected significantly by EGR. However particulate matter emission in the exhaust increases.

**Baert R. S, Beckman D.E, et al. [3]** they studied Efficient EGR technology for future HD diesel engine emission targets in this study, this research has been extrapolated towards lower emission levels. Exhaust gas recirculation (EGR) was applied to a modern EURO-3-type HD diesel engine. The corresponding fuel matrix covers a range of fuel oxygen mass fractions up to 15%. Results are presented and the impact of fuel oxygen mass fraction and Cetane Number are analyzed and compared with results from previous research.

**Moser FX, Sams T, et al. [4]** they have studied Impact of future exhaust gas emission legislation on heavy duty truck engine. Exhaust gas recirculation (EGR) is an upcoming technology for heavy duty (HD) engines and they made a study on modern power cylinder technologies to EGR driven needs and concluded that NOx is reduced by EGR technique and PM increases.

**K.Rajan and K.R.Senthilkumar [5]** they studied the effect of EGR on the performance and emission characteristic of diesel engine with Sunflower Oil Methyl Ester. They observed that B20 SFME with 15% EGR rate produce 25% less NOx emissions compared to diesel fuel for the same level smoke emissions.

**Deepak Agarwal, Shrawan Kumar Singh, et al. [6]** They investigate the effect of EGR on soot deposits, and wear of vital engine parts, especially piston rings, apart from performance and emissions in a two cylinder, air cooled, constant speed direct injection diesel engine, Reductions in $NO_X$ and exhaust gas temperature were observed but emissions of particulate matter (PM), HC and CO were found to have increased with usage of EGR.

**Heywood J B [7]** they studied and published the paper on Pollutant Formation and control in internal combustion engine. They states that NO is formed during post flame combustion process in high temperature region and by implementation of EGR reduces NOx emission. The present paper focuses on implementation of hot and cold EGR in a diesel engine. This is achieved by modifying an engine.

## 2. EXPERIMENTAL SETUP

The experimental set-up is shown in the below Figure 1, which is computerized single cylinder four stroke, naturally aspirated direct injection and air cooled diesel engine. The specifications of the test engine are given below. Engine is loaded with an eddy current dynamometer. Engine is equipped with AVL GH12D miniature pressure transducer for measuring the pressure variation in the cylinder and AVL 615 Indimeter software which measures the heat release rate from the measured values of cylinder pressure at different crank angle. AVL 5 gas analyzer was used for measuring the CO, UHC, NOx, CO2 and AVL Smoke meter was used for measuring the smoke opacity. For circulation of exhaust gases into the intake manifold an EGR set up was provided which consists of a control valve and manometer. For obtaining cold EGR exhaust gas is been stored in a tank and cooled to a predefined temperature before it is send back into the cylinder. The amount of exhaust gas recirculated is calculated before it is send into the engine. The amount of exhaust gas recirculated is calculated using the following formula,

$$\%\ \text{EGR} = \frac{\text{Volume of EGR}}{\text{Total intake charge into the cylinder}} \times 100$$

In the present experiment the flow of the exhaust gas is controlled by a valve. The exhaust gas is recirculated into the stream of fresh air which is taken from the atmosphere through a pipe. The exhaust gas and fresh air are mixed with each other before they are sent into the cylinder. Both the flow rates of the fresh air and exhaust air are calculated using a U- tube manometer.

### 2.1 Engine Specification

Variable Compression Ratio Diesel Engine
No of Cylinder=1
No of Stroke=4
Fuel= Diesel
Vertical water cooled
Power=3.5 KW, 1500 RPM
Compression Ratio=12 to 18
Modified VCR Engine Compression Range =12 to 18

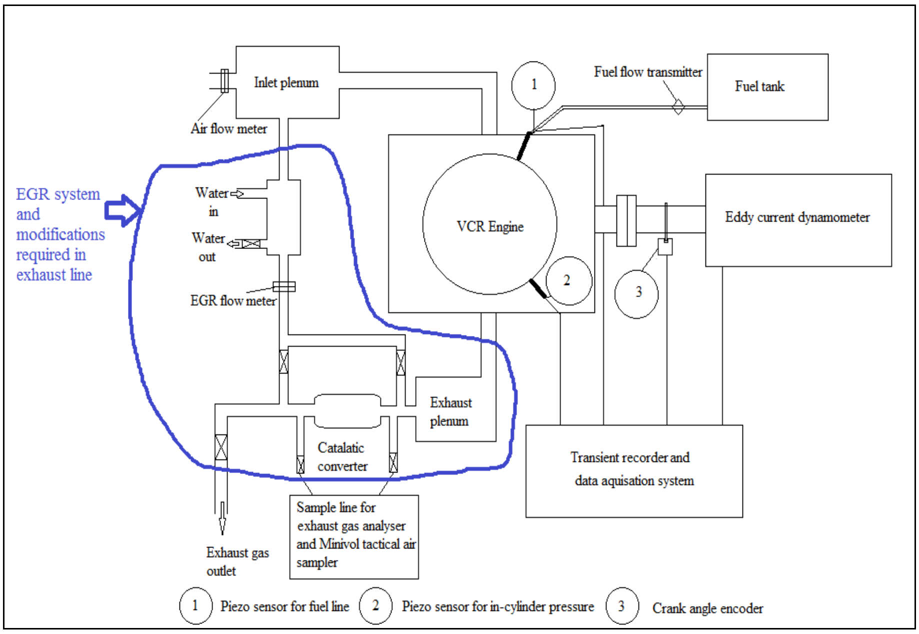


Fig 1: Line Diagram of Experimental Setup

CC=661
Eddy Current Dynamometer with water cooling
Cylinder Diameter=87.5mm
Stroke Length=110mm
Connecting Rod Length=234mm
Compression Ratio Very=12 to 18:1

### 2. 2 Experimental Procedure

The engine is operated at a constant speed of 1500 rpm. The first stage of experiment was performed with diesel at different loads from no-load to full load (0%,25%,50%,75%,100%) without EGR at constant speed and different compression ratio (15,16,17,17.5,18). Engine loads are adjusted by using eddy current dynamometer. Exhaust gases are tapped from exhaust pipe and connected to inlet airflow passage so the EGR is hot. The rate of EGR is varied with the help of EGR control valve which is fixed in the pipe control. The second stage of experiment was performed with diesel at different loads from no-load to full load (0%,25%,50%,75%,100%) with EGR rates such as 0%, 5%,10%,15% and 20% at constant speed and different compression ratio (15,16,17,17.5,18). Engine loads are adjusted by using eddy current dynamometer. Exhaust gases are tapped from exhaust pipe and they are stored in a drum for a certain time so as to reach the desired temperature and then connected to inlet airflow passage.

## 3. RESULTS AND DISCUSSION

### 3.1 Performance Analysis

#### *3.1.1 Brake Thermal Efficiency (BTE)*

Results obtained by performing the experiment are presented in the graphical form as shown in the below graphs. The variation of the brake thermal efficiency along the different loads is presented in graph by taking load on X axis and BTE on Y axis as shown in figure 2. It is evident from the graph that the brake thermal efficiency increases with the load and the maximum possible brake thermal efficiency will be at the maximum load.

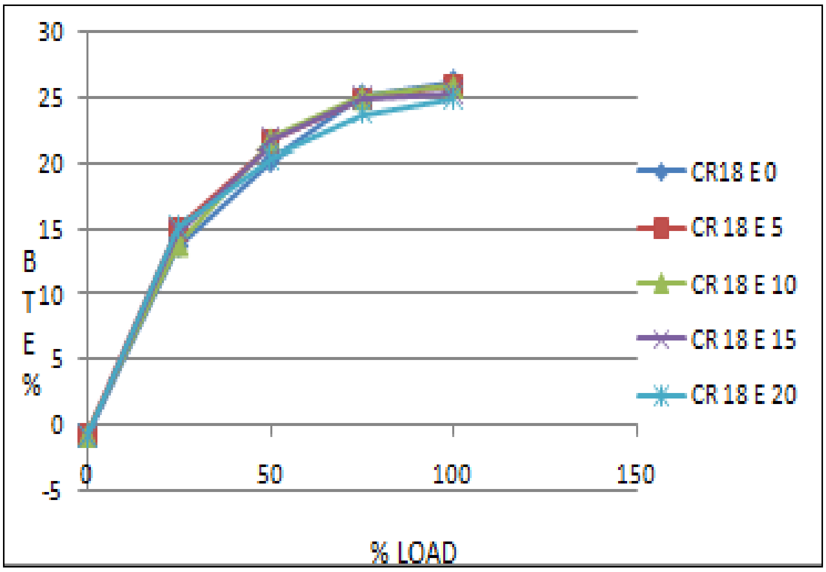


Fig 2: Variation of Brake Thermal Efficiency with Load for Different Percentages of EGR

#### *3.1.2 Specific Fuel Consumption*

The variation of the specific fuel consumption (SFC) along the different loads and different EGR is presented in graph by taking load on X axis and SFC on Y axis as shown in figure 3. It can be observed from the graph that brake specific fuel consumption decreases as the load increases. As the EGR rate is increases.

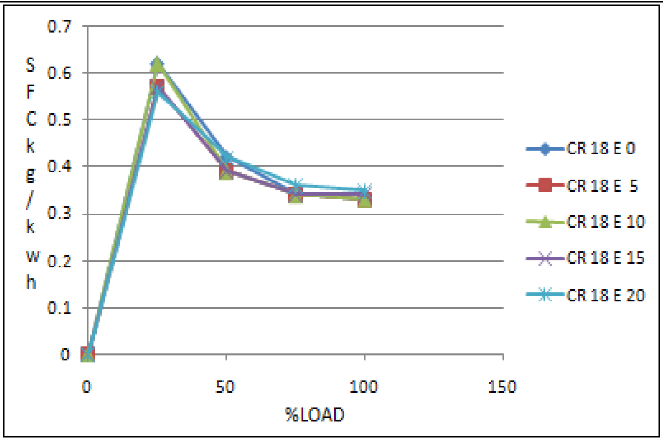


Fig 3: Variation of Brake Specific Fuel Consumption with Load for Different Percentages of EGR

## 3.2 Emission Analysis

### *3.2.1 CO Emissions*

The variation of the CO emissions along the different loads is presented in graph by taking load on X axis and CO on Y axis as shown in figure 4. It shows that CO increases with EGR.

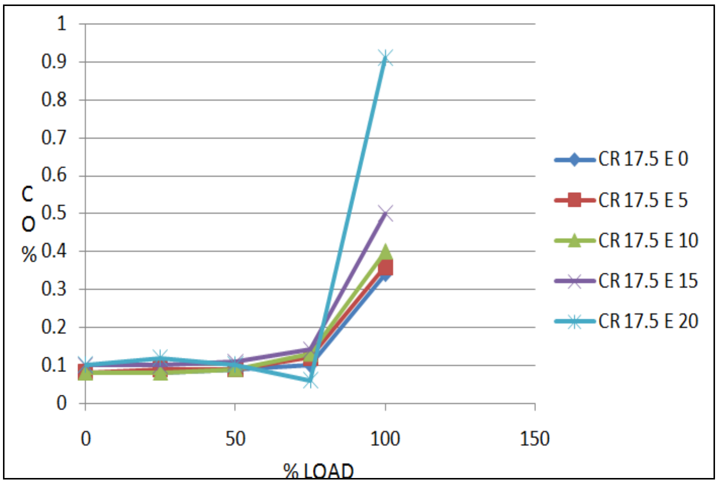


Fig 4: Variation of CO Emissions with Load for Different Percentages of EGR

### *3.2.2 NO Emissions*

The variation of the NOx emissions along the different loads is presented in graph by taking load on X axis and NOx on Y axis as shown in figure 5. Graph shows that the NO is reduced when EGR is increased.

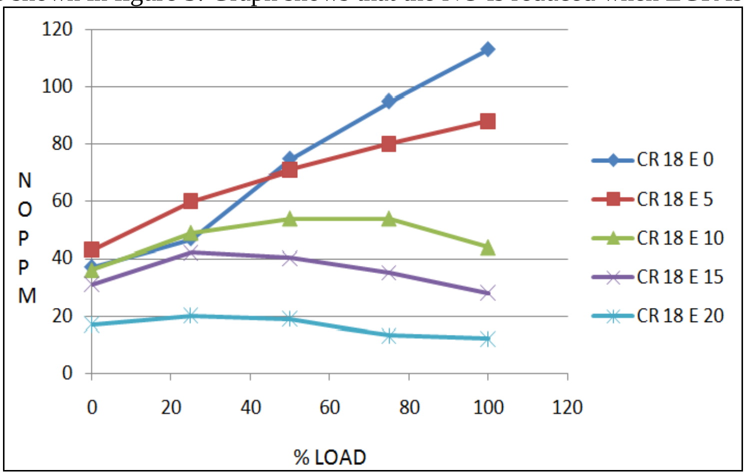


Fig 5: Variation of NO Emissions with Load for Different Percentages of EGR

### *3.2.3 Smoke*

The variation of the smoke along the different loads is presented in graph by taking load on X axis and smoke on Y axis as shown in figure 6. The smoke increases slightly as the EGR rates increases. This is because of the recirculation of exhaust gases into the cylinder.

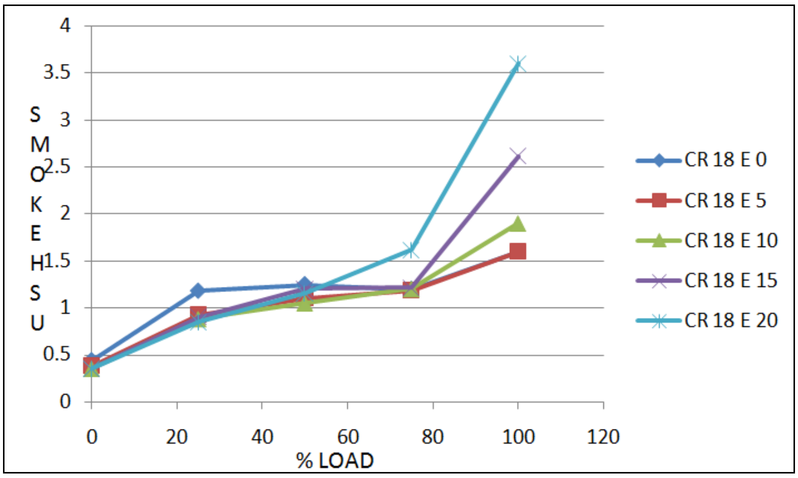


Fig 6: Variation of Smoke with Load for Different Percentages of EGR

## 4. Conclusion

From the obtained experimental results, fallowing conclusions can be drawn.

EGR is a very useful technique for reducing the NOx emission. EGR displaces oxygen in the intake air and dilute the intake charge by recirculating the exhaust gas to the combustion chamber. Recirculated exhaust gas lower the oxygen concentration in combustion chamber and increase the specific heat of the intake air mixture, which results in lower flame temperatures. It was observed that 20% EGR rate is found to be effective to reduce NOx emission substantially without deteriorating engine performance in terms of thermal efficiency, BSFC and emissions. Thus, it can be concluded that higher rate of EGR can be applied at lower loads and lower rate of EGR can be applied at higher load. EGR can be applied to diesel engine without sacrificing its efficiency and fuel economy and NOx reduction can thus be achieved.

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