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Impact of EGR on Performance of CI Engine

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Abstract - With the ever – increasing prices of gasoline, the diesel engines are replacing petrol engines at a faster rate, both in the field of vehicular and stationary applications. Attention of the public and researchers have focused mainly on diesel engines. Fuel reformulation as one of these key technologies is being seriously considered for smoke reduction. Exhaust gas Recirculation (EGR) has proved to be effective in reducing NOx. The tests have been conducted on a twin cylinder Dl diesel engine. Engine was modified for testing effect of EGR. Experiments are also conducted with 0%, 9%, 13% 21% and 26% EGR. Effect of EGR on smoke, NOx and other performance parameters such as brake specific fuel consumption, exhaust gas temperature, smoke density and brake thermal efficiency are evaluated.

The experimentations were carried out on Exhaust Gas Recirculation on a four-stroke twin cylinder engine. It is proved that the exhaust gas recirculation has definite impact on NOx reduction. However this drop is at the expense of increase in smoke and fuel consumption. The smoke can be controlled using various smoke additives. Brake thermal efficiency decreases marginally with increasing EGR rates. Exhaust gas temperature incases with increase in EGR rates as the exhaust gas that is recirculated has higher temperature than the temperature of inlet air which results in increases in temperature of inlet air.

Keywords - EGR, Brake thermal efficiency, Smoke density, Exhaust gas temperature, Nox.

I. INTRODUCTION

The rise in civilization is closely related to the improvements in transportation. IC engines, both petrol and diesel engines, occupy a very important position in every day life. The diesel engines have provided the power units for transportation system, i.e. buses and goods transportation system i.e. trucks. In recent times the IC engine powered vehicles have come under heavy attack due to various problems created by them. The most serious of these problems is air pollution, where as the main problem facing the developing countries is pollution. India however faces the same severe problem of pollution in her metropolitan cities. The pollutants from vehicle do not amount too much, it is about 1 Kg of pollutants per day, but for large number of vehicles this amount rises very rapidly. The pollution amount becomes millions of tones. So the serious attempts should be made to conserve earth's environment from degradation.

Reaction that occurs in the engines combustion process not only produce numerous products of combustion such as CO_2, H_2O but also the gases which are subjected to legal limitation like CO, HC, Smoke and Sox. The pollutants contained in exhaust emission are aldehydes, NOx, soot etc. of these smoke and NOx are under heavy attack due to the stringent emission norms coming up. Oxides of Nitrogen (NO, NO_2, and N_2O_2 etc.) are found at high combustion temperatures present in the engine. Ninety five percent of NOx is occupied by No, which is odorless gas and affects the function of the lungs. It irritates man's mucous membranes and oxidizes with O_2 to produce NO_2.

The reduction in NOx formation during the actual combustion process is mainly due to the drop in the maximum temperature reached or due to the reduced oxygen concentration. Water injection or EGR or the combination of one of these methods with injection timing retard may achieve the reduction in NOx formation.

In most of today's IDI and DI heavy-duty diesel engine vehicles, EGR is used as very effective means to reduce NOx emissions in order to comply with the most stringent light duty diesel engines NOx standards. The present work in undertaken to study the impact of Exhaust Gas Recirculation on NOx emission and performance of four-stroke twin cylinder engine.

II. EXPERIMENTAL SETUP

A large number of instruments were needed for experimentations and measurements. The setup for EGR was fabricated by using various components required. Schematic diagram of experimental setup is shown in figure no.1. Various measurements taken include, speed, load, fuel consumption, airflow rate, EGR flow rate, smoke density and NOx measurement. Out of all the instruments used in the fabrication of the experimental setup, venturimeters and heat exchanger were designed and fabricated as per the requirements.

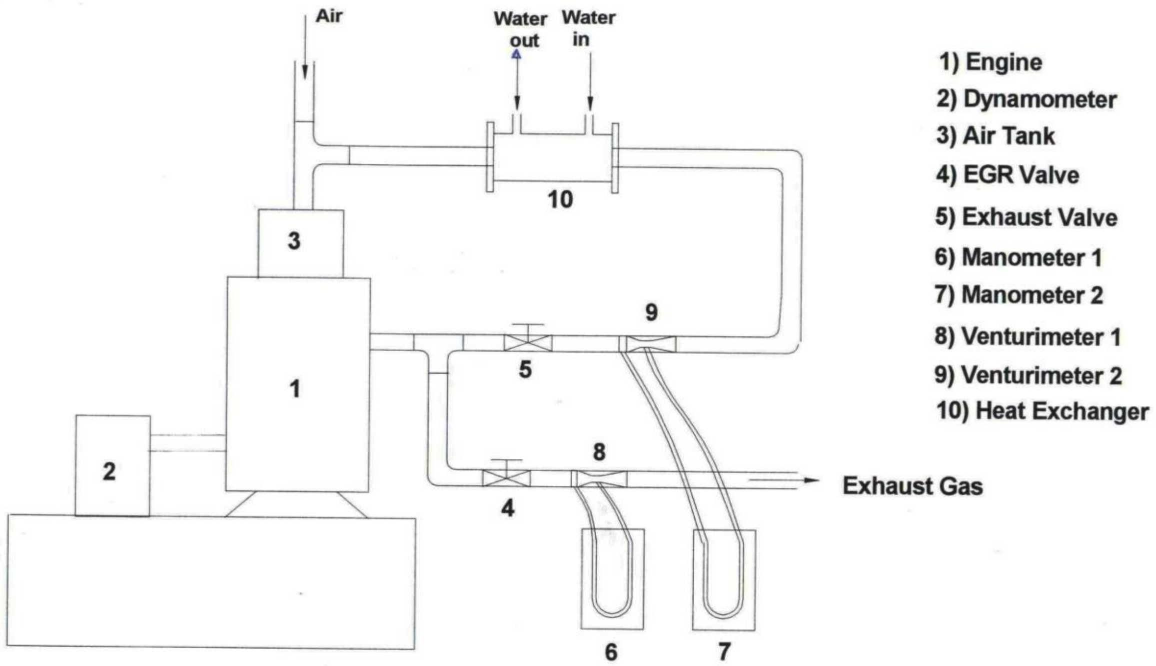

Figure 1. Experimental Setup

Engine Specifications:

Make	Kirloskar, Double cylinder Four Stoke Compression ignition engine
Rated power output	7.5 K W
Speed	188 RPM
Stroke length	110 mm
Bore diameter	80 mm
Displacement	55.264 CC
Moment Arm	0.214 m
Orifice diameter	25 mm
Coefficient of Discharge of orifice	0.64

III. PROCEDURE FOR ENGINE TESTING

The C.I. engine was tested for its performance at different EGR rates. Testing was carried out at various loads starting form no load to 20 Kg. The tests were carried out at constant speed of 1800 rpm. Engine was coupled with dynamometer for loading arrangement. Venturimenters were used for measurement of EGR rate and exhaust gas flow. Initially the engine was run at no load condition. The EGR valve was kept fully closed. All the parameters like fuel consumption, smoke density, exhaust gas flow were measured. Then EGR valve was opened partially, allowing the exhaust gas to enter into the inlet manifold. Again all the parameters were noted for a given EGR rate. Several readings were taken at no load condition for different EGR rate. Same procedure was repeated for the different load conditions.

3.1 NOx Measurement

Oxides of nitrogen, which also occur in the engine exhaust, are a combination of nitric oxide (NO) and Nitrogen dioxide (NO_2). Nitrogen and oxygen react at relatively high temperatures. Therefore high temperature and availability of oxygen are the two main reasons for the formation of NOx. When the proper amount of oxygen is available, higher the peak combustion temperature the more is the NO formation. The NOx is formed in the atmosphere as NO oxidizes. The instrument used for NOx measurement was Spectrophotometer and the method was Jacob and Hoiser method.

3.2 Procedure of NOx Measurement

1. First of all a sample of exhaust gas from engine was collected in urobag (2lit. capacity).
2. 25 ml of alkaline solution of sodium arsenite (absorbent) was taken into the impinge.
3. Smoke was passed through the absorbent at slow rate (0.5 lit/min) to absorb the NOx from exhaust gas.
4. After absorption of all NOx in sodium arsenite solution, Hydrogen peroxide (H_2O_2) (1 ml), salphanialmide (5 ml) and NEDA (1 ml) was added. The mixture was shaked and kept for 15 minutes. The colourless solution was changed in to purple colour. The dark purple colour indicates more quantity of NOx in as sample and faint purple colour indicates lower quantity of NOx.
5. A coloured sample of solution is taken into cuvette, a wavelength of 550 nanometer was adjusted in spectrophotometer and sample was kept into the spectrophotometer.
6. After passing a light of 550 nanometer digital indicator indicates the total absorbance of NOx in a sample.
7. From calibration curve NOx was measured in $\mu g/m^3$.

IV. RESULTS AND DISCUSSION

To study the impact of Exhaust Gas Recirculation (EGR) on performance and NOx emission of diesel engine, tests were conducted at various load with different EGR rates.

4.1 Effect of EGR On NOx

Figure 2 and table 2 shows variation of NOx concentration with different EGR rates. It clearly indicates that with increase in EGR rate, the concentration of NOx decreases. The reason behind this is, exhaust gas, which is recirculated, does not take part in combustion processes and it absorbs some energy and hence lowers the peak combustion temperature which ultimately results in to reduction of NOx.

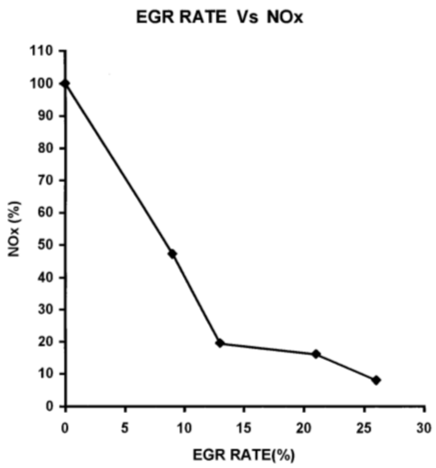

Figure 2. Effect of EGR on NOx Percentage

Table 2.: Variation of NOx with EGR

Sr. No.	%EGR	NOx (μg/m^3)	NOx (%)	Reduction in NOx (%)
1	0	32,756	100	0
2	9	15,464	47	53
3	13	6,394	20	80
4	21	5,264	16	84
5	26	2,610	8	92

4.2 Effect of EGR ON Exhaust Gas Temperature

Figure 3 and table 3 shows variation of Exhaust Gas Temperature with load at different EGR rates. It appears that exhaust gas temperature rises with increasing EGR rates. This may be because of higher temperature of EGR than the inlet air temperature.

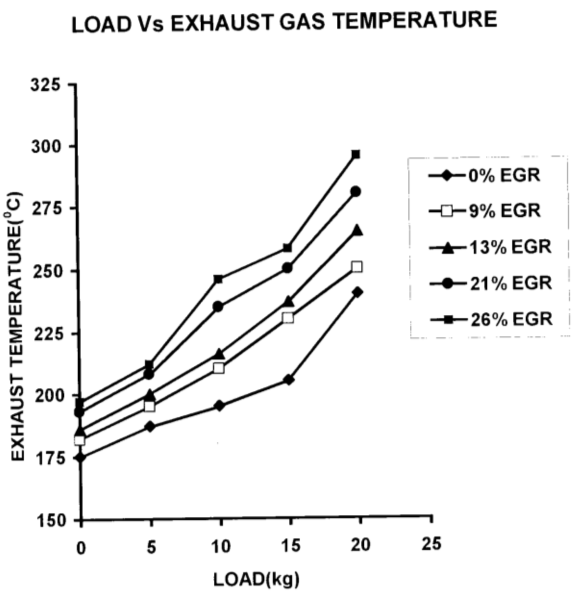

Figure 3. Effect of EGR on Exhaust Gas Temperature

Table 3.: Variation of Exhaust Gas Temperature with EGR

Sr.No.	Load (Kg)	Exhaust Gas Temperature ^{0}C				
		0 % EGR	9 % EGR	13 % EGR	21 % EGR	26 % EGR
1	0	175	182	186	193	197
2	5	187	195	200	208	212
3	10	195	210	216	235	246
4	15	205	230	237	250	258
5	20	240	250	265	280	295

4.3 Effect of EGR On Brake Thermal Efficiency

Figure 4 and table 4 shows variation of brake thermal efficiency with load at different EGR rates. There was a very small change in efficiency at a particular load with different EGR rates. It is clear from the figure 4., with increasing rates of EGR at different load there is slight decrease in brake thermal efficiency. This may be because of the following factors.

1. Oxygen deficiency at higher load, which leads to incomplete combustion.
2. Increase in heat loss with exhaust gases. It can be seen from the figure 4.2 that exhaust gas temperature increases with increasing EGR rates for the same load range.
3. EGR lowers the maximum temperature of the cycle.

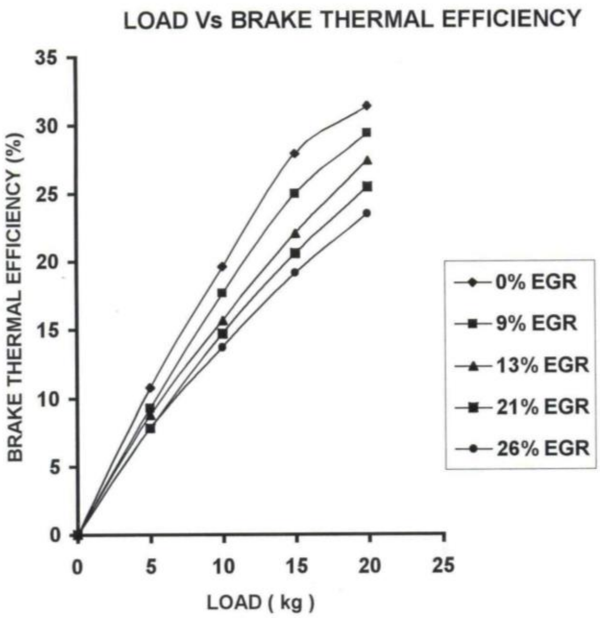

Fig 4. Effect of EGR on Brake Thermal Efficiency

Table 4.: Variation of Brake Thermal Efficiency with EGR

Sr.No.	Load (Kg)	Brake Thermal Efficiency (%)				
		0 % EGR	9 % EGR	13 % EGR	21 % EGR	26 % EGR
1	0	0	0	0	0	0
2	5	10.77	9.3	8.81	7.83	7.83
3	10	19.58	17.62	15.66	14.69	13.71
4	15	27.9	24.96	22.03	20.56	19.09
5	20	31.33	29.37	27.41	25.45	23.5

4.4 Effect of EGR on Smoke Density

It can be seen from figure 5 and table 5 that the smoke emission increases in EGR rates for all loading conditions. This significant increase in smoke is probably due to following reasons.

1. EGR reduces the overall air/fuel ration which enhances the increase in particulates. Further reduction in air/fuel ratio due to progressive increase in intake manifold temperature, with increasing EGR rate promotes smoke formation.
2. Recirculated exhaust gas also contains smoke, which further contribute in raising smoke level.

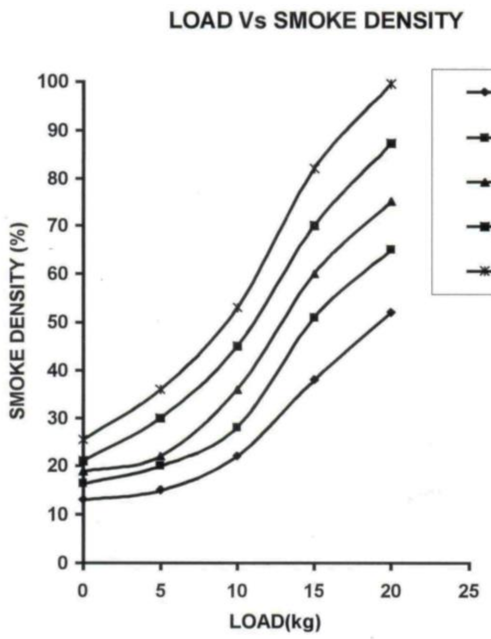

Fig 5. Effect of EGR on Smoke Density

Table 5.: Variation of Smoke Density with EGR

Sr.No.	Load (Kg)	Smoke Density (%)				
		0 % EGR	9 % EGR	13 % EGR	21 % EGR	26 % EGR
1	0	13	16.4	18.9	21	25.4
2	5	15	20	22	30	36
3	10	22	28	36	45	53
4	15	38	51	60	70	82
5	20	52	65	75.2	87.3	99.5

V. CONCLUSIONS

The following conclusions are drawn after carrying out the experimentation on Exhaust Gas Recirculation on a four-stroke twin cylinder engine.

1. It is proved that the exhaust gas recirculation has definite impact on NOx reduction. However this drop is at the expense of increase in smoke and fuel consumption. The smoke can be controlled using various smoke additives.

2. Brake thermal efficiency decreases with increasing EGR rates. However this decrease is marginal and it can be tolerated in view of its effect on environment and health of human being in particular.
3. Exhaust gas temperature increases with increase in EGR rates as the exhaust gas that is recirculated has higher temperature than the temperature of inlet air, which results in increases in temperature of inlet air.

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