Performance and Emission Analysis of Exhaust Gas Recirculation (EGR) System on Diesel Engine

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***Abstract*- It is today undoubted that humans have to reduce their impact on the environment. Internal combustion engines, being the major power source in the transportation sector as well as in individual transport, play an important role in the man-made emissions. While the mobility in the world is growing, it is important to reduce the emissions that result from transportation. Exhaust Gas Recirculation (EGR) System means to use the Exhaust Gas coming from Exhaust Manifold to Inlet Manifold in order to reduce the Emission of NOX, which is particularly very harmful. Engine without EGR are more pollutant & uses more atmospherically air for combustion. By Implementation of EGR system in Engine, the Partial Exhaust Gas is re-circulated again in Engine. It is first cooled in EGR Cooler & then it is mixed with atmospheric air & then passed to Combustion Chamber. Fresh atmospheric air required is reduced & automatically pollutant (CO, CO2, HC, NOx etc.) is reduced. The aim of this work is to review the potential of exhaust gas recirculation (EGR) to reduce the exhaust emissions, particularly NOx Emissions, and to delimit the application range of this technique. The purpose of project is to plot the graph between Brake power (B.P.) Vs. NOX, B.P. Vs. CO2, B.P. Vs CO with & without implementation of EGR. The Major Task of the proposed work includes Calculation of NOX content in I.C. Engine with or without the Implementation of EGR System. The system is very much Eco Friendly. Using Exhaust Gas Recirculation (EGR) Technique in engines, the emissions are very much controlled. This method is very reliable in terms of fuel consumption.**
Keywords: Exhaust Gas Recirculation, NOx Emissions, I.C. Engine, Inlet Manifold, Exhaust Manifold

I. INTRODUCTION

The survey of CI engine application it is found that there is challenge to increases engine performance and reduces emission from the engine. As we know that CI Engines are better power source due to higher compression ratio, higher efficiency, performance, and reliability than SI Engines. Hence, in most of on-road transportation, and off-road stationary applications, CI Engines are widely used. Exhaust gas from the engine is re-circulated by using outside bypass provided. Exhaust gas having capability of absorbing oxygen content from the air because of these combustion flame temperature is decreases. It was reported that, Unequal EGR distribution results in increased NOx and PM emissions compared to engine running with well mixed air and EGR gases. Furthermore, the increase in emissions was due to cylinder-to cylinder variations in both gas composition and intake temperature. He was also concluded that, the suppression of unequal cylinder-to-cylinder EGR distribution results in a large reduction of NOx and PM emissions, especially when running with high EGR rates.

The Exhaust Gas Recirculation (EGR) system is designed to reduce the amount of Oxides of Nitrogen (NOX) created by the engine during operating periods that usually result in high combustion temperature. NOX is formed in high concentrations whenever combustion temperature exceeds about 2500ºF. EGR is an effective method for NOX control. The exhaust gases mainly consist of inert carbon dioxide, nitrogen and possess high specific heat. When recalculated to engine inlet, it can reduce oxygen concentration and act as a heat sink. This process reduces oxygen concentration and peak combustion temperature, which results in reduced NOX. EGR is one of the most effective techniques currently available for reducing NOX emissions in internal combustion engines. However, the application of EGR also incurs penalties. It can significantly increase smoke, fuel consumption and reduce thermal efficiency unless suitably optimized. The higher NOX emission can be effectively controlled by employing EGR.

II. LITERATURE REVIEW

N.k. Miller jothi et al., studied the effect of Exhaust Gas Recirculation (EGR) on homogeneous charge ignition engine. A stationary four stroke, single cylinder, direct injection (DI) diesel engine capable of developing 3.7 kW at 1500 rpm was modified to operate in Homogeneous Charge Compression Ignition (HCCI) mode. In the present work the diesel engine was operated on 100% Liquefied Petroleum Gas (LPG).

The LPG has a low cetane number (<3), therefore Diethyl ether (DEE) was added to the LPG for ignition purpose. DEE is an excellent ignition enhancer (cetane number >125) and has a low auto ignition temperature (160 ◦C). Experimental results showed that by EGR technique, at part loads the brake thermal efficiency increases by about 2.5% and at full load, NO concentration could be considerably reduced to about 68% as compared to LPG operation without EGR. However, higher EGR percentage affects the combustion rate and significant reduction in peak pressure at maximum load.

Table 2.1: Technical specifications of engine

Parameter	Specification
Bore X Stroke	144.3 mm x 139.7mm
Displacement volume	553 cm^3
Compression ratio	16.5 : 1
Type of cooling	Water cooled
Rated power	3.7kw @ 850rpm

The parameters and their specifications are been listed in table 2.1.
Deepak Agarwal et al., 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, which is typically used in agricultural farm machinery and decentralized captive power generation. Such engines are normally not operated with EGR. Emissions of hydrocarbons (HC), NOX, carbon Monoxide (CO), exhaust gas temperature, and smoke capacity of the exhaust gas etc. were measured. Performance parameters such as thermal efficiency, brake specific fuel consumption (BSFC) were calculated. Reductions in NOX and exhaust gas temperature were observed but emissions of particulate matter (PM), HC and CO were found to have increased with usage of EGR. The engine was operated for 96 hr in normal running conditions and the deposits on vital engine parts were assessed. The engine was again operated for 96 h with EGR and similar observations were recorded. Higher carbon deposits were observed on the engine parts operating with EGR. Higher wear of piston rings was also observed for engine operated with EGR.

III. EXPERIMENTAL SETUP & METHODOLOGY

Single cylinder four stroke computerised diesel engine is selected. Computer can be used for the control of a test and data acquisition, thus improving the efficiency of engine testing. The computer can also process all data, carry out statistical analysis, and plot all the result. Engine Soft is useful for testing and analysing performance of various parameter of engine. EGR system is designed and then fabricated by considering specification of engine. There are two type of EGR system by considering temperature, first is hot EGR system, in these system hot gasses is directly recalculated in the engine and second is cold EGR system, in this exhaust gasses is cooled by using EGR cooler. Cold EGR system is more effective than hot EGR system. Show that photograph of computerised single cylinder four stroke engines without installing EGR system. Brief specifications of engine are given below. Moreover, all tests will be conducted and parameters will be measured under steady state operation. Table 3.1 explains briefly about the specifications of engine used for our work.

Table 3.1 Engine specifications

Engine type	**Single Cylinder four stroke diesel engine**
Displacement	436 CC
Maximum Power	8 KW
Maximum RPM	850 RPM
Fuel Type	Diesel

Figure: 3.1 without EGR

The EGR system will fabricated as per requirements shown in fig 3.1. The set-up will then, modified by incorporating exhaust gas recirculation subsystem in the set-up as shown. A short cooled EGR system will choose for study due to its merits.

The necessary components for EGR set-up fittings are
I. EGR Cooler
II. EGR Valve
III. Gas Pipe connection
IV. Control Valve

Figure: 3.2 with EGR Setup

A baffle is placed at equidistance from each other and is shown in fig. 3.2. Total length of Cooler is 600 mm. Flow arrangement selected is counter flow because of high rate of heat transfer. For respective EGR valve position decrease in difference in manometer column will observed compared to (without EGR) total intake charge suction. This decrease in column is nothing but mass of exhaust gas re-circulated during respective valve position. Therefore, this value of mass of exhaust gas re-circulated will determined. We have the total suction during without EGR. This interprets rate of EGR circulated. If EGR valve is totally closed no exhaust gas is circulated. EGR Specifications are given in table 5.2 as shown below.

Table 5.2 EGR Specification

Component	Specification
EGR cooler	Shell and tube
Type of flow	Counter flow
Shell fluid	Water coolant
Tube Fluid	Gas
Core length	600mm
Shell diameter	150mm
EGR valve (Gate valve)	Manually operated
Gas pipe GI	2 inch

IV. DEVELOPMENT OF EGR SYSTEM

Increased demands are being placed on engine manufacturers to design and build engines that provide better engine performance, improved reliability and greater durability while meeting more stringent emission and noise requirements. One important object for internal combustion engine designers is to reduce NOX emissions, while minimizing any negative impact on engine fuel economy and durability. An internal combustion engine having an exhaust gas recirculation (EGR) system reduces NOX emissions while substantially maintaining fuel economy and durability. In many systems, for example, EGR is cooled to reduce NOX emission levels at high engine loads. Systems in which EGR is not cooled may experience relatively high NOX emissions during heavy engine throttle or loads. On the other hand at low engine loads, systems in which EGR is cooled experience fuel droplets vaporization which is not enhanced. Large fuel droplets affect emission by producing soot.

4.1 Benefits of EGR from MTU

Generally speaking, systems designed to reduce emissions must be modified to match the drive systems. MTU has produced a very compact design that permits all the exhaust gas recirculation components to be integrated into the engine concept, so that any modifications to the engine have relatively little effect on space requirements and the exhaust system. It is necessary to modify the radiator, however, in order to cope with the increased cooling capacity of the engine. Compared to engine modifications involving an SCR system, this makes it much easier for customers to convert their units to meet new emissions standards because EGR systems for reducing nitrogen oxides require no additional operating media and thus involve no further expense.

4.2 Principle of Operation

In exhaust gas recirculation, some of the exhaust gas is drawn off from the exhaust system, cooled and redirected back into the cylinders. Although the exhaust fills the combustion chamber, it is not involved in the combustion reaction that takes place in the cylinder due to its low oxygen content. The speed of the combustion process overall is thus reduced, with the result that the peak flame temperature in the combustion chamber is lowered. This dramatically reduces the production of nitrogen oxides.

4.3 Cooling System for Exhaust Gas Recirculation

The exhaust gas drawn off for recirculation has a temperature of around 650 degrees Celsius. It is therefore far too hot to be fed directly into the cylinders; it would increase the temperature of the combustion chamber even further, thereby defeating its actual purpose — that of reducing nitrogen oxide formation by lowering the combustion temperature. For this reason, the exhaust gas is first cooled to around 120 degrees Celsius. In the case of industrial engines with high intake air and exhaust mass flow rates that requires high cooling capacities, which have to be supplied by high-performance heat exchangers.

In principle, proven volume-production coolers as used in the commercial vehicle sector can be adopted for the purpose. However, to cover the cooling capacity required for a 16-cylinder engine with a capacity of 4.8 liters per cylinder, depending on the supplier, four to eight conventional commercial vehicle radiators of the highest capacity available would be needed for exhaust gas recirculation. Using this number of single radiators with the required mechanical strength is not possible in a mobile application.

V. EXPERIMENTAL PROCEDURE WITHOUT EGR SYSTEM

The experiment was carried out on a single cylinder, air cooled, four stroke diesel engine. Engine was first started and kept in running condition up to 10 minutes. After that we set the speed of engine as 850 rpm (Tachometer was used). Once rpm was set we observed time (by stopwatch) required by engine to consumed 10 cc/sec of fuel (Diesel) and then Temperature at Exhaust 8 manifold was measured (with the help of infrared Thermometer and thermocouple). Calculations for different parameters (BP, TFC,FP,IP,ηBT, ηIT, η$MECH$,BSFC etc.) were calculated by obtained time and temperature.

The experiments was further carried out by setting speed of engine as 850 rpm and time required by engine to consumed 10 cc/sec of fuel and exhaust gas temperature were measured. The relevant difference of measurement of time and temperature between various rpm was approximately 10 minutes i.e. after each measurement, engine was kept in running condition up to approximately 10 minutes and then time and temperature were calculated and further calculations of various parameters were done.

5.1 Result and Discussion (Without EGR)

Table 5.1 without EGR

Sl.no	Units	1	2	3	4
Spring Balance Load $W2$	**Kg**	0	0.1	0.5	1.5
Weight In Hanger $W1$	**Kg**	0	5	10	15
Net Load $W1$-$W2$	**N**	0	48.069	93.195	127.53
Speed	**RPM**	830	820	811	792
Time Taken Form Fuel	**10cc/s ec**	67.31	53.19	42.19	37.19
TFC $1\times10-4$	kg/s	1.229	1.559	1.96	2.22
Fuel Power	**kW**	5.567	7.044	8.878	10.087
BP	**kW**	0	0.8511	1.632	2.264
FP	**kW**	2	2	2	2
IP	**kW**	2	2.8511	3.632	4.264
ηBT	**%**	0	12.082	18.38	22.44
ηIT	**%**	32.33	40.47	40.71	42.27
$\eta MECH$	**%**	0	29.85	45.14	53.08
BSFC	$kJkW.hr/$	0	0.6594	0.4323	0.353

5.2 Calculation Without EGR System

Speed of Engine, N = 850 RPM
Calorific value, CV = 45300 kJ/kg
Radius of flywheel of engine, r = 0.2062m
Density, ρ=827.5 kg/m3

1) TFC=$10\times10-6\rho T$=$10\times10-6\times827.553.19$=$1.559\times10-4kg/sec$
2) FP=TFC×CV=1.559×10−4×45300=7.044kW
3) BP=$2\pi NT60\times1000$=$2\times\pi\times820\times48.069\times0.0206260\times1000$=0.8511 kW
4) IP= Friction Power +Brake Power=2+0.8511=2.8511kW
5) ηBT=$BPFuel Power\times100$=0.85117.044×100=12.082%
6) ηIP=$IPFuel Power\times100$=2.85117.044×100=40.47%
7) $\eta mech$=$BPIP\times100$=0.85112.8511=29.85%
8) BSFC=$TFC\times3600BP$=1.559×10−4×36000.8511=0.6577$kJ / kW.hr$

Where, TFC=Total Fuel Consumption
BP=Brake Power
FP=Friction Power
IP= Indicate Power
ηBT=Brake Thermal Efficiency
ηIT=Indicate Thermal Efficiency
$\eta mech$=Mechanical Efficiency
BSFC=Brake Specific Fuel Consumption

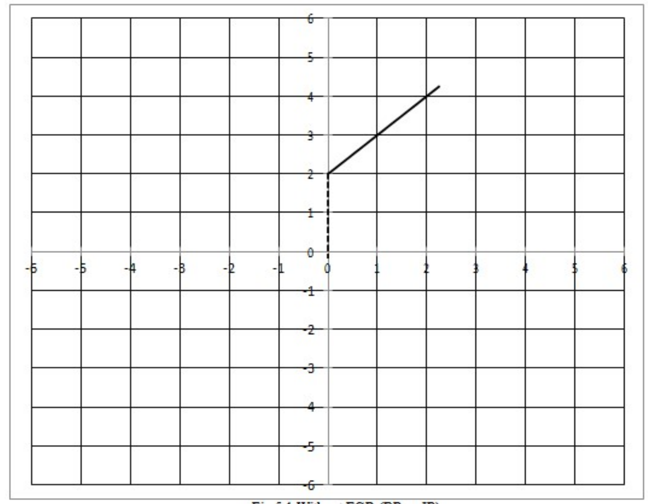

Figure 5.1 Without EGR (BP vs IP)

5.3 Performance of an Engine Without EGR System

The variation of Exhaust Gas Temperature of the engine without EGR system at various Brake Power is shown in Figure 5.2. As shown, when Brake power of the engine increases, Exhaust Gas Temperature of the engine also increases. The brake power of the engine varies from 0 kW to 2.348 kW and respectively Exhaust Gas

The variation of fuel consumption of the engine without EGR system at various Brake Power is shown in Figure 5.3. As shown, when Brake power of the engine increases, the fuel consumption of the engine is also increases. The brake power of the engine varies from 0 kW to 2.348 kW and fuel consumption varies from 0.6945 kg/hr to 0.984 kg/hr respectively.

The variation of brake thermal efficiency of the engine without EGR Power is shown in Figure5.4. As shown, when Brake power of the engine increases, the Brake thermal efficiency of the engine is also increases. The brake power of the engine varies from 0 kW to 2.348 kW and respectively, brake thermal efficiency varies from 0 to 26.775 %.

Table 5.2 Emission (without EGR system)

Speed in RPM	Weight in kg	B.P. in kW	CO %	CO2 %	NOx PPM	HC PPM
830	0	0	0.43	0.027	300	198
820	5	0.8511	.0.46	0.028	311	201
811	10	1.632	0,44	0.03	350	209
792	15	2.264	0.45	0.032	402	225

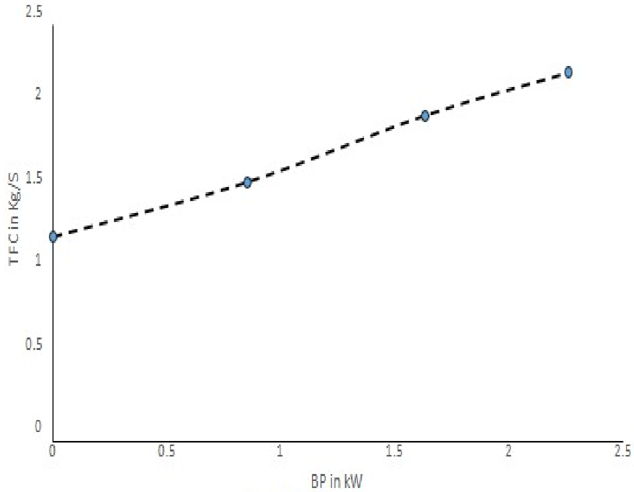

Fig5.2 TFC Vs BP

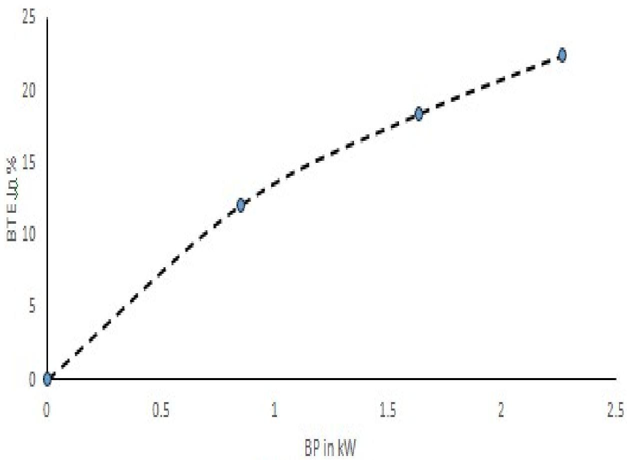

Fig 5.3 BTE Vs BP

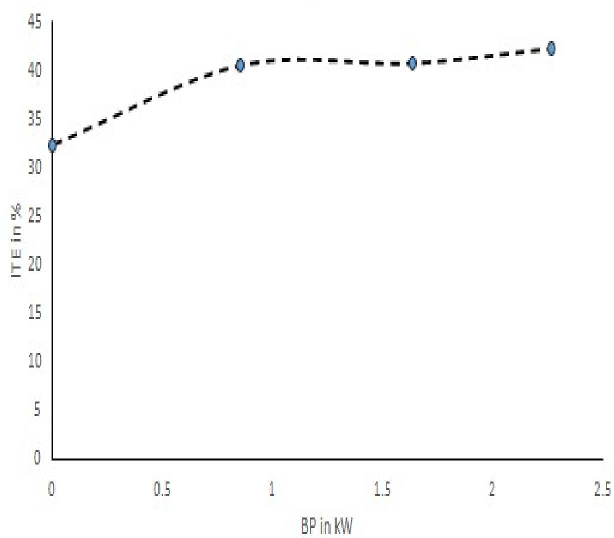

Fig 5.4 ITE Vs BP

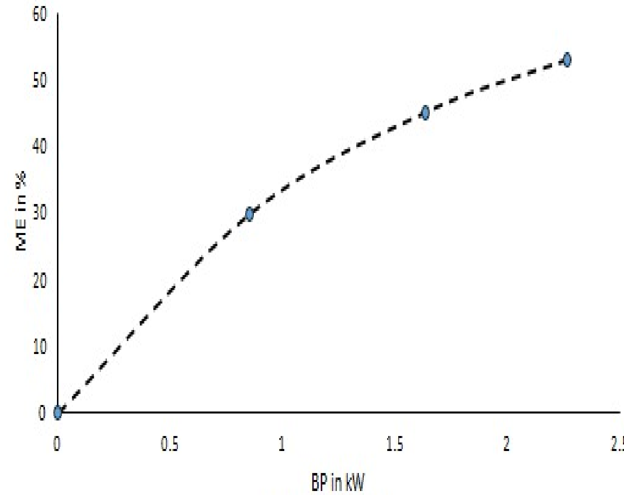

Fig 5.5 ME Vs BP

5.4 Emission (Without EGR System)

The variation of Carbon Monoxide (CO) of the engine without EGR system at various Brake Power is shown in Figure 5.6. An irregular graph is obtained practically, but theoretically it is proved that as brake power increases emission of CO from Engine also increases. As per as brake power of the engine varies from 0 kW to 2.264 kW and Carbon Monoxide (CO) varies from 0.43 % to 0.45 %.

CO Vs BP

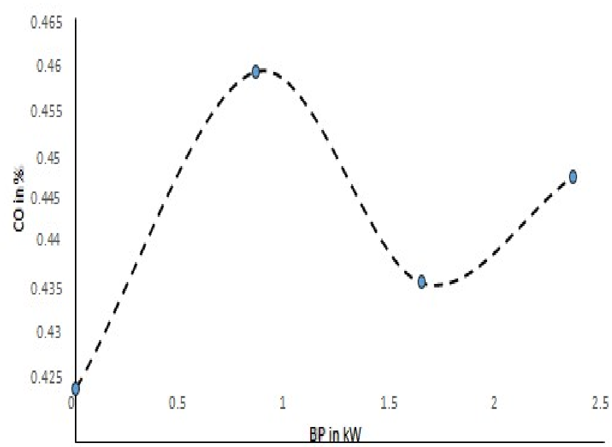

Fig 5.6 CO Vs BP

The variation of Carbon Dioxide (CO2) of the engine without EGR system at various Brake Power is shown in Figure 5.7. As shown when Brake power of the engine increases, Emission of Carbon Dioxide (CO2) of the engine is also increases. The brake power of the engine varies from 0 kW to 2.264 kW and Carbon Dioxide (CO2) varies from 0.027 % to 0.032 %.

CO_2 Vs BP

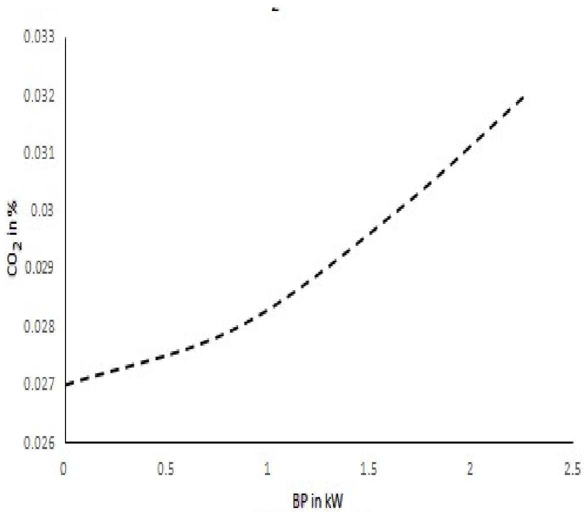

Fig 5.7 CO_2 Vs BP

The variation of Nitrogen Oxide (NOx) of the engine without EGR system at various Brake Power is shown in Figure 5.8. As shown, when Brake power of the engine increases, Emission of Nitrogen Oxide (NOx) of the engine also increases. The brake power of the engine varies from 0 kW to 2.264 kW and Emission of Nitrogen Oxide (NOx) varies from 300 ppm to 402 ppm.

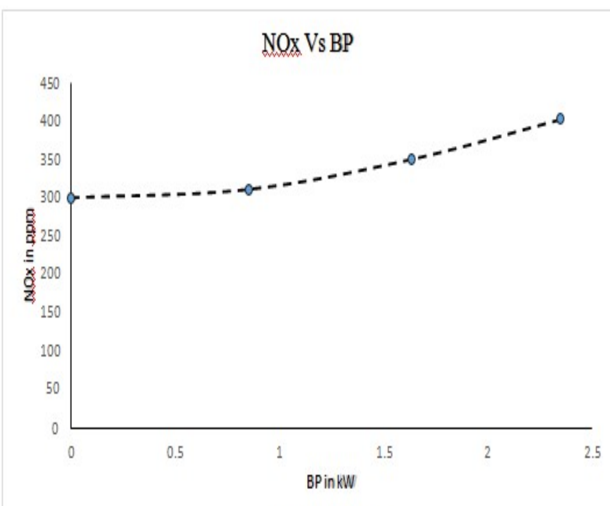

Fig 5.8 NOx Vs BP

The variation of Hydro Carbon (HC) of the engine without EGR system at various Brake Power is shown in Figure 5.9. As shown, when Brake power of the engine increases, Emission of Hydro Carbon (HC) of the engine decreases. The brake power of the engine varies from 0 kW to 2.64 kW and Emission of Hydro Carbon (HC) varies from 198 ppm to 225 ppm.

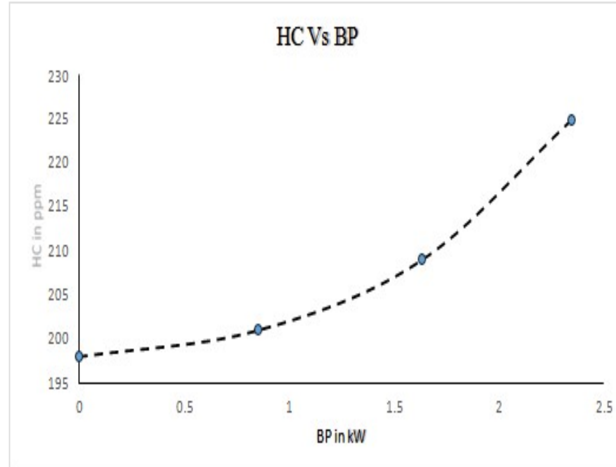

Fig 5.9 HC Vs BP

VI. EXPERIMENTAL PROCEDURE WITH EGR SYSTEM

The experiment was carried out on a single cylinder, air cooled, four stroke diesel engines. It was necessary to make some of modifications in the engine since the original engine had no EGR. It was necessary to connect the exhaust manifold with the air intake manifold. The experimental set-up and comprises a diesel particulate air filter, a heat exchanger, a liquid fuel metering systems, and an exhaust gases analysis system. It was necessary to connect the exhaust manifold with the air intake manifold.

A tachometer is connected with engine; it is use for measuring RPM of the engine. The EGR pipe connected with exhaust manifold to the inlet of the engine. The EGR pipe also connected with intercooler and air filter as shown in, The air filter is used for particulate reduction and supply of clean gas for EGR. The intercooler is used as an exhaust cooler for cooling exhaust gas.

Procedure for measurement and calculation of various parameters i.e. time (required by engine to consumed 10cc/sec of fuel at various rpm), temperature, BP, TFC,FP,IP,ηBT, ηIT, $\eta MECHANICAL$,BSFC, etc was same as that carried out for without EGR system.

6.1 Result and Discussion (With EGR)

Table 6.1 With EGR system

Sl.no	units	1	2	3	4
Spring Balance Load $W2$	kg	0	0.7	1.6	2.5
Weight In Hanger $W1$	kg	0	5	10	15
Net Load $W1$-$W2$	N	0	42.183	82.404	122.625
Speed	RPM	910	900	890	870
Time Taken Form Fuel	10cc/sec	50.87	44.91	38.31	35.81
TFC $1\times10-4$	kg/s	1.626	1.842	2.16	2.31
Fuel Power	kW	7.365	8.344	9.7848	10.464
BP	kW	0	0.8197	1.5836	2.3036
FP	kW	3.1	3.1	3.1	3.1
IP	kW	3.1	3.9197	4.6836	5.43036
ηBT	%	0	9.823	16.185	22.014
ηIT	%	42.09	46.97	47.86	51.63
η$MECH$	%	0	20.91	33.81	42.63
BSFC	kJ / $kW.hr$	0	0.808	0.491	0.513

6.2 Calculation of Performance an Engine with EGR System

Speed of Engine, N = 850 RPM
Calorific value, CV = 45300 kJ/kg
Radius of flywheel of engine, r = 0.2062m
Density, ρ=827.5 kg /m3

1) TFC=10×10−6ρT=10×10−6×827.544.91=1.842×10−4k $gsec$/
2) FP=TFC×CV=1.842×10−4×45300=8.344kW
3) BP=2πNT60×1000=2×π×900×42.183×0.0206260×1000=0.8197 kW
4) IP= Friction Power + Brake Power=3.1+0.8197=3.9197kW
5) ηBT=$BPFuel\ Power$×100=0.81978.344×100=9.823%
6) ηIP=$IPFuel\ Power$×100=3.91978.344×100=46.97%
7) η$mech$=$BPIP$×100=0.81973.9197=20.91%
8) BSFC=TFC×3600BP=1.626×10−4×36000.8197=0.808 kJ / $kW.hr$

Where, TFC=Total Fuel Consumption
BP=Brake Power
FP=Friction Power
IP=Indicate Power
ηBT=Brake Thermal Efficiency
ηIT=Indicate Thermal Efficiency
η$mech$=Mechanical Efficiency
BSFC=Brake Specific Fuel Consumption

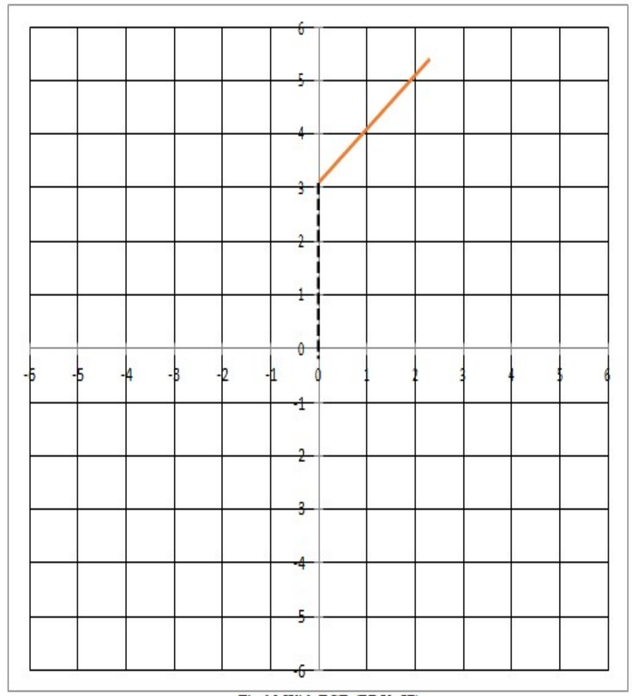

Fig 6.1 With EGR (BP Vs IP)

6.3 Performance of an Engine With EGR System

The variation of Total fuel consumption of the engine with EGR system at various Brake Power is shown in Figure 6.2. As shown, when Brake power of the engine increases, Exhaust Gas Temperature of the engine also increases.
The brake power of the engine varies from 0 kW to 2.3036 kW and Total fuel consumption.

The variation of the brake thermal efficiency of the engine with EGR system at various Brake Power is shown in Figure 6.3. As shown, when Brake power of the engine increases, Brake thermal efficiency of the engine also increases. The brake power of the engine varies from 0 kW to 2.3036 kW.

The variation of indicate thermal efficiency of the engine with EGR system at various Brake Power is shown in Figure 6.4. As shown, when Brake power of the engine increases, fuel consumption of the engine also increases. The brake power of the engine varies from 0 kW to 2.3036 kW and indicates thermal efficiency.

The variation of the mechanical efficiency of the engine with EGR system at various Brake Power is shown in Figure 6.5. As shown, when Brake power of the engine increases, Brake thermal efficiency of the engine also increases. The brake power of the engine varies from 0 kW to 2.3036 kW and mechanical efficiency.

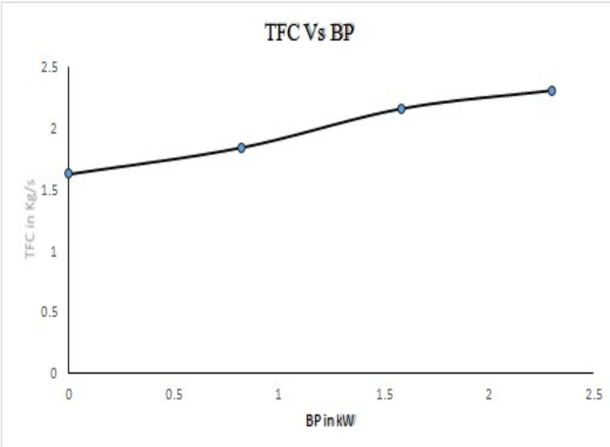

Fig6.2 TFC Vs BP

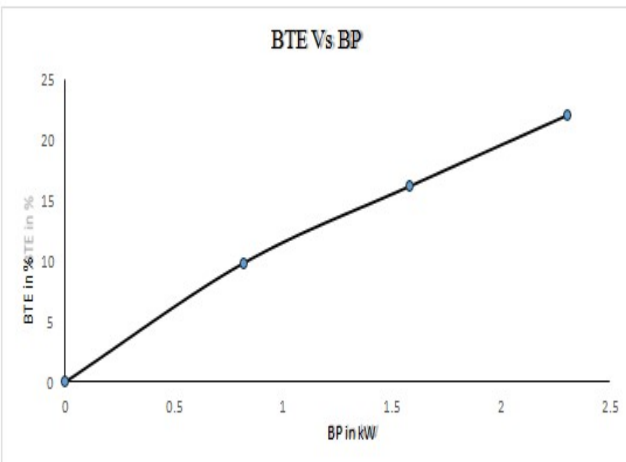

Figure 6.3 BTE Vs BP

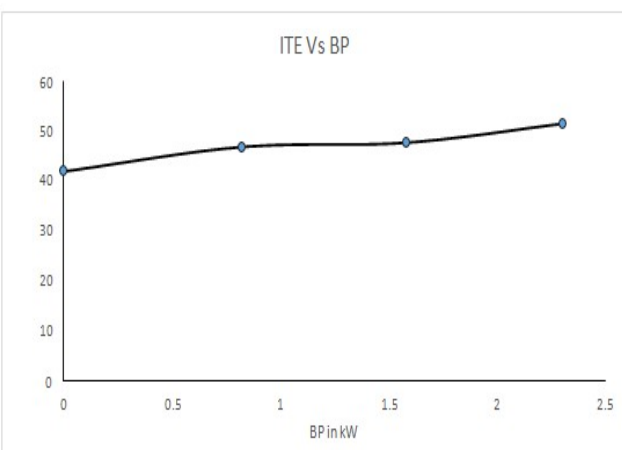

Fig 6.4 ITE Vs BP

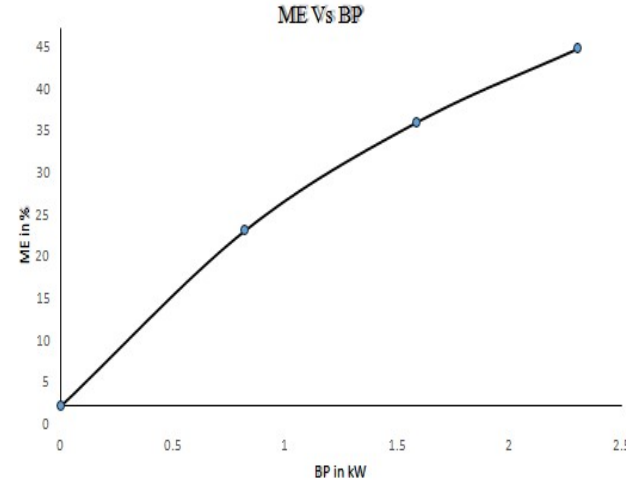

Fig 6.5 ME Vs BP

6.4 Emission with EGR System

The variation of Carbon Monoxide (CO) of the engine with EGR system at various Brake Power is shown in Figure 6.6. When Brake power of the engine increases, Emission of Carbon Monoxide (CO) of the engine also increases. The brake power of the engine varies from 0 kW to 2.3036 kW and Emission of Carbon Monoxide (CO) varies from 0.43 % to 0.41 %.

The variation of Emission of Carbon Dioxide (CO2) of the engine with EGR system at various Brake Power is shown in Figure 6.7. As shown, when Brake power of the engine increases, Emission of Carbon Dioxide (CO2) of the engine also increases. The brake power of the engine varies 0 kW to 2.464 kW and Emission of Carbon Dioxide (CO2) varies from 0.032% to 0.036 %.

The variation of Nitrogen Oxide (NOx) of the engine with EGR system at various Brake Power is shown in Figure 6.8. As shown, when Brake power of the engine increases, Emission of Nitrogen Oxide (NOx) of the engine also increases. The brake power of the engine varies from 0 kW to 2.3036 kW and Emission of Nitrogen Oxide (NOx) varies from 125 ppm to 165 ppm.

The variation of Emission of Hydro Carbon (HC) of the engine with EGR system at various Brake Power is shown in Figure 6.9. As shown, when Brake power of the engine increases, the Emission of Hydro Carbon (HC) of the engine decreases. The brake power of the engine varies from 0 kW to 2.3036 kW and CO2 Vs BP Emission of Hydro Carbon (HC) varies from210 ppm to 313ppm.

Table 6.2 briefs about the details of Emission with EGR system.

Table 6.2 Emission (with EGR system)

Speed in RPM	Weight in Kg	B.P. in kW	CO %	CO2 %	NOX Ppm	HC Ppm
910	0	0	0.43	0.032	125	210
900	5	0.8197	0.46	0.033	145	275
890	10	1.5836	0.44	0.036	156	317
870	15	2.3036	0.41	0.037	165	313

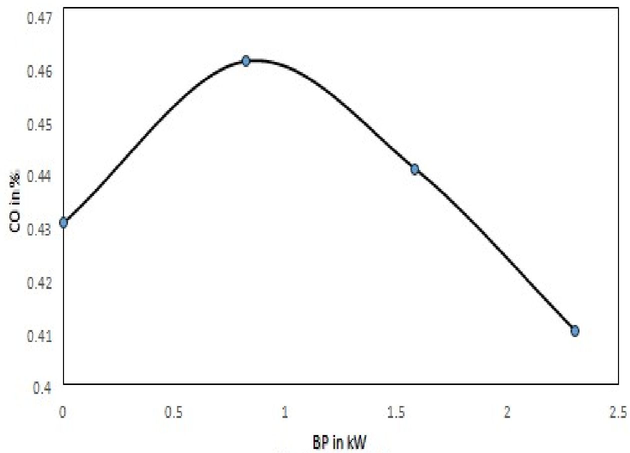

Fig 6.6 CO Vs BP

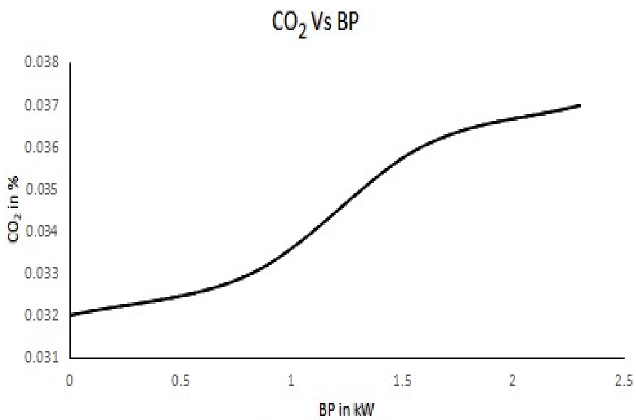

Fig 6.7 CO2 Vs BP

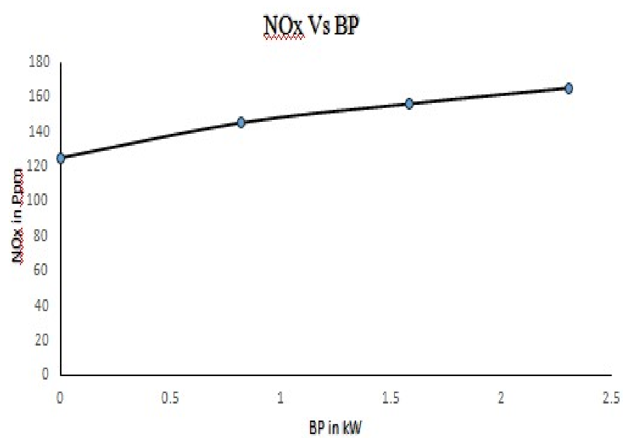

Fig 6.8 NOx Vs BP

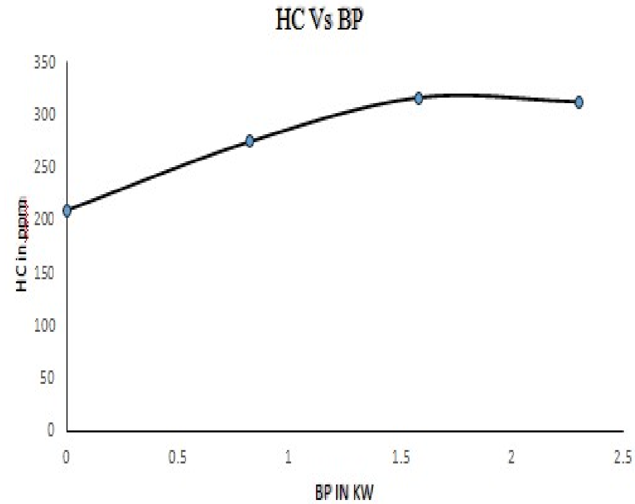

Fig 6.9 HC Vs BP

VII. COMPARISON PERFORMANCE OF AN ENGINE WITH & WITHOUT EGR SYSTEM

Figur7.1 shows Comparison graph of with and without EGR system of variation in Total fuel consumption with respect to Brake Power. From the above figure it is clear that the value of Exhaust Gas Temperature of the diesel engine with EGR is less than that of without EGR system at same brake power.

Figure7.2 shows Comparison graph of with and without EGR system of variation in Fuel Power with respect to Brake Power. From the above figure it is clear that the value of Fuel Consumption of the diesel engine with EGR is more than that of without EGR system at same brake power.

Figure7.3 shows Comparison graph of with and without EGR system of variation in Indicate Power with respect to Brake Power. From the above figure it is clear that the value of Fuel Consumption of the diesel engine with EGR increases than that of without EGR system at same brake power.

Figure7.4 shows Comparison graph of with and without EGR system of variation in Brake Thermal Efficiency with respect to Brake Power. From the above figure it is clear that the value of Fuel Consumption of the diesel engine with EGR increases than that of without EGR system at same brake power.

Figure7.5 shows Comparison graph of with and without EGR system of variation in Emission of CO with respect to Brake Power. From the above figure it is clear that the value of Emission of CO of the diesel engine with EGR is less than that of without EGR system at same brake power.

Figure 7.6 shows Comparison graph of with and without EGR system of variation in Emission of CO2 with respect to Brake Power. From the above figure it is clear that the value of Emission of CO2 of the diesel engine with

EGR is less than that of without EGR system at same brake power.

Figure 7.7 shows Comparison graph of with and without EGR system of variation in Emission of NOx with respect to Brake Power. From the above figure it is clear that the value of Emission of NOx of the diesel engine with EGR is less than that of without EGR system at same brake power

Figure 7.8 shows Comparison graph of with and without EGR system of variation in Emission of HC with respect to Brake Power. From the above figure it is clear that the value of Emission of HC of the diesel engine with EGR is more than that of without EGR system at same brake power.

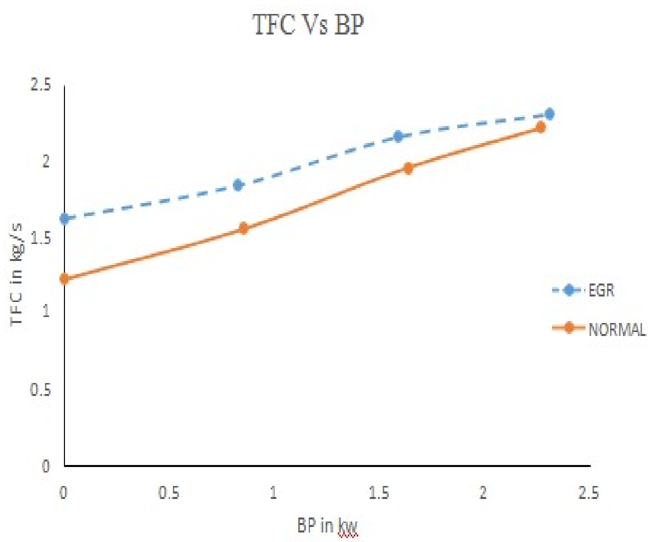

Fig7.1 TFC Vs BP

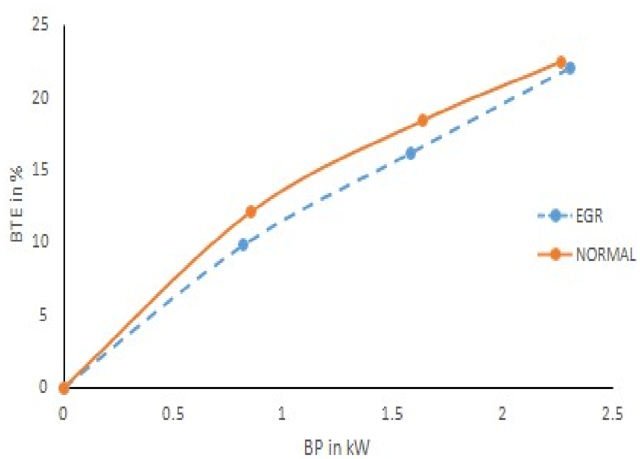

Fig 7.2 BTE Vs BP

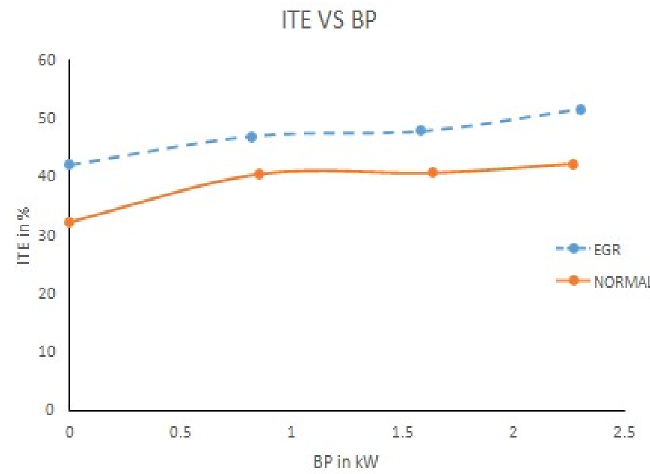

Fig 7.3 ITE Vs BP

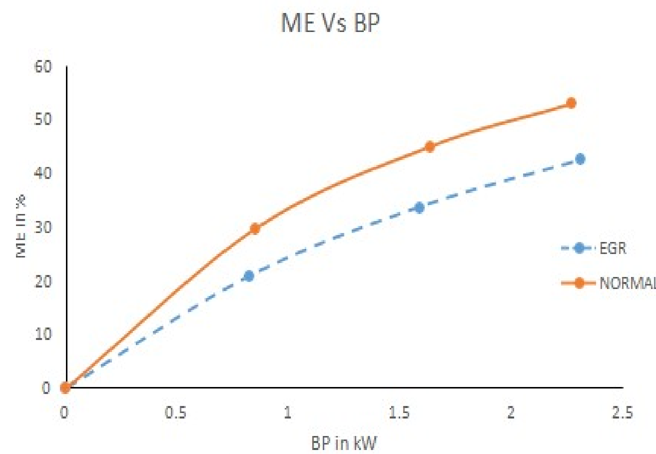

Fig 7.4 ME Vs BP

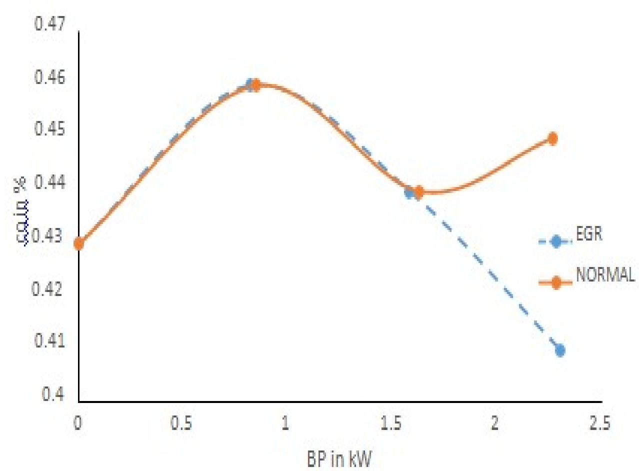

Fig 7.5 CO Vs BP

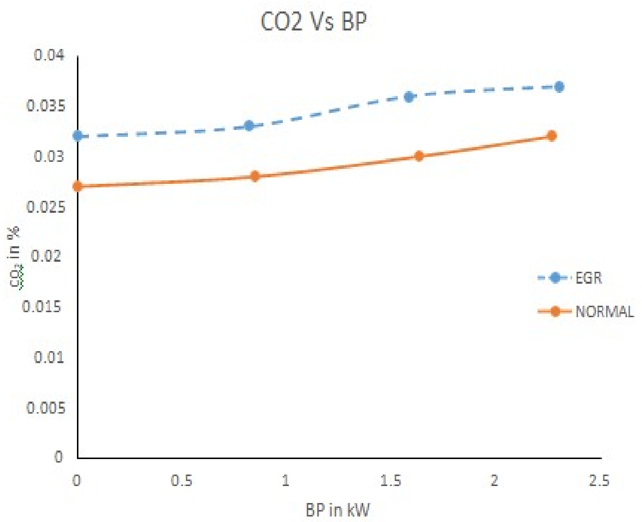

Fig 7.6 CO_2 Vs BP

VIII. CONCLUSION

The main objective of the present investigation was to evaluate suitability of Exhaust Gas Recirculation system for use in a C.I. engine and to evaluate the performance and emission characteristics of the engine. The experimental study shows the following results

- The engine performance on EGR system, Exhaust Gas Temperature reduces as compared to that of without EGR system, so it is beneficial for surrounding.
- Comparison graph of with and without EGR system of variation in Fuel Consumption with respect to Brake Power. it is clear that the value of Fuel Consumption of the diesel engine with EGR increases than that of without EGR system at same brake power.
- The Brake Thermal Efficiency (BTE) of the engine was partially lower and the Brake Specific Fuel Consumption (BSFC) of the engine was partially higher when EGR system was implemented with engine.
- Emission of Oxide of Nitrogen (NOx) was very much reduced by implementation of EGR system.
- Emission of Carbon Dioxide (CO2) and Carbon Mono-oxide (CO) was also reduced.
- Emission of Hydro Carbon (HC) increases by implementing EGR system with engine than that of operating engine without EGR system.

REFERENCES

[1] N.K. Miller Jothi, G. Nagarajan, S. Renganarayanan; LPG fueled diesel engine using diethyl ether with exhaust gas recirculation, International Journal of Thermal Sciences 47 (2008) 450–457.

[2] Deepak Agarwal , Shrawan Kumar singh, Avinash Kumar Agarwal; Effect of Exhaust Gas Recirculation (EGR) on performance, emissions, deposits and durability of a constant speed compression ignition engine, Applied Energy 88 (2011) 2900–2907.

[3] H.E. Saleh; Effect of exhaust gas recirculation on diesel engine nitrogen oxide reduction operating with jojoba methyl ester, Renewable Energy 34 (2009) 2178–2186.

[4] N.Saravanan, G.Nagarajan, K.M.Kalaiselvan, C. Dhanasekaran; An experimental investigation on hydrogen as a dual fuel for diesel engine system with exhaust gas recirculation technique, Renewable Energy 33 (2008) 422– 427.

[5] M.L.Mathur, R.P. Sharma, 2003 Internal Combustion Engine (New Delhi: Dhanpat Rai Publications) pp 760 - 776.

[6] V Ganeshan, 2007, Internal Combustion Engines Inc.end.(New York: Mc-Graw Hill), pp 480-499.

[7] S.Ghosh,D.Dutta,’’ Performance & emission parameters analysis of gasoline engine with EGR’’,IJERD,vol 4,issue 10,(Nov 2012),pp 8-12.

[8] Vipul Jain,Dinesh Singh Parihar,Vaibhav Jain & irfan H Mulla,”Performance of Exhaust Gas Recirculation (EGR) system on Diesel Engine”,IJERA,vol.3,Issue 4,2013,pp.1287-1297.