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

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Abstract

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, AVL Gas Analyze, Infrared Thermometer*

I. Introduction

The Exhaust Gas Recirculation (EGR) system is designed to reduce the amount of Oxides of Nitrogen (NO_X) created by the engine during operating periods that usually result in high combustion temperature. NO_X is formed in high concentrations whenever combustion temperature exceeds about 2500ºF.

The EGR system reduces NO_X production by re-circulating small amounts of exhaust gases into the intake manifold where it mixes with the incoming air/fuel charge. By diluting the air/fuel mixture under these conditions, peak temperature and pressure are reduced, resulting in an overall reduction of NO_X output. Generally speaking EGR flow should match following operating conditions:

- High EGR flow is necessary during cruising and mid range acceleration, when combustion temperature is typically very high.
- Low EGR flow is needed during low speed and light load condition
- No EGR flow should occur during conditions when EGR operation could adversely affect engine operating efficiency or vehicle drive ability (engine warm up, idle, wide open throttle, etc.)

EGR is an effective method for NO_X control. The exhaust gases mainly consist of inert carbon dioxide, nitrogen and possess high specific heat. When recirculated 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 NO_X. EGR is one of the most effective techniques currently available for reducing NO_X 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 NO_X emission can be effectively controlled by employing EGR.

II. Literature Review

In internal combustion (IC) engines, exhaust gas recirculation (EGR) is a nitrogen oxide (NO_X) 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.

N.k. Miller jothi et al., [1] 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% Liquified 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 1.1 Technical Specifications of the Engine

Parameter	Specification
Bore × Stroke	80mm x 110mm
Displacement volume	553 cm^3
Compression ratio	16.5:1
Type of cooling	Water cooled
Rated power	3.7KW @ 1500rpm

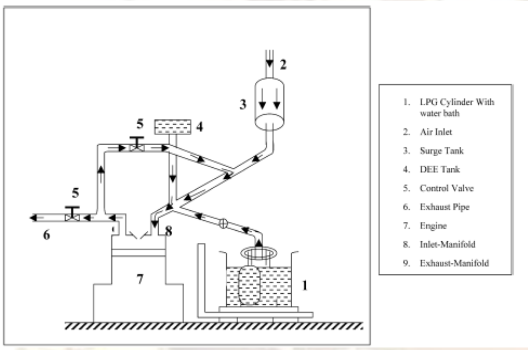

Fig.1.1 Schematic View of the EGR Setup.

Deepak Agarwal et al., [2,3] 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. The experiments were carried out to experimentally evaluate the performance and emissions for different EGR rates of the engine. Emissions of hydrocarbons (HC), NO_X, 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 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. 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.

Table 1.2 Technical Specifications of the Engine

Engine type	Two cylinder, direct injection
Bore / stroke	87.3 / 110mm
Rated power	9 KW
Rated speed	1500 rpm
Compression ratio	16:5:1
Total displacement volume	13181
Fuel injection release pr.	210 bar
Inlet valve open/inlet valve close	45° BTDC/ 35.5° ATDC
Exhaust valve opens/ exhaust valve closes	35.5° BBDC/ 45° ATDC

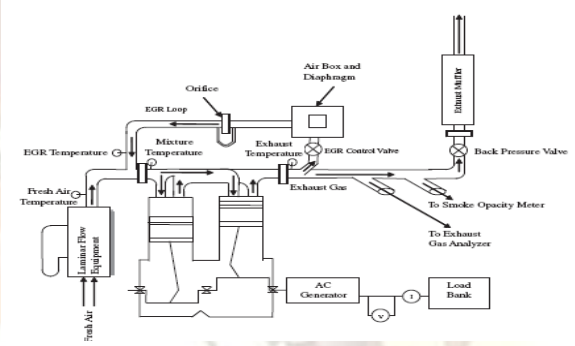

Fig.1.2 Schematic Diagram of Engine Setup using EGR.

H.E.Saleh [4] studied Jojoba methyl ester (JME) has been used as a renewable fuel in numerous studies evaluating its potential use in diesel engines. These studies showed that this fuel is good gas oil substitute but an increase in the nitrogenous oxides emissions was observed at all operating conditions. The aim of this study mainly was to quantify the efficiency of exhaust gas recirculation (EGR) when using JME fuel in a fully instrumented, two-cylinder, naturally aspirated, four-stroke direct injection diesel engine. The tests were carried out in three sections.

Firstly, the measured performance and exhaust emissions of the diesel engine operating with diesel fuel and JME at various speeds under full load are determined and compared.

Secondly, tests were performed at constant speed with two loads to investigate the EGR effect on engine performance and exhaust emissions including nitrogenous oxides (NO_X), carbon monoxide (CO), unburned hydrocarbons (HC) and exhaust gas temperatures. Thirdly, the effect of cooled EGR with high ratio at full load on engine performance and emissions was examined.

The results showed that EGR is an effective technique for reducing NO_X emissions with JME fuel especially in light-duty diesel engines. With the application of the EGR method, the CO and HC concentration in the engine out emissions increased. For all operating conditions, a better trade-off between HC, CO and NO_X emissions can be attained within a limited EGR rate of 5–15% with very little economy penalty.

III. Experimental Setup & Methodology

Table 1.3 Engine Specifications

Engine Type	Single Cylinder, Naturally Aspirated Air Cooled
Displacement	436.00 CC
Maximum Power	5.53 KW
Maximum RPM	3600 RPM
Fuel Type	Diesel

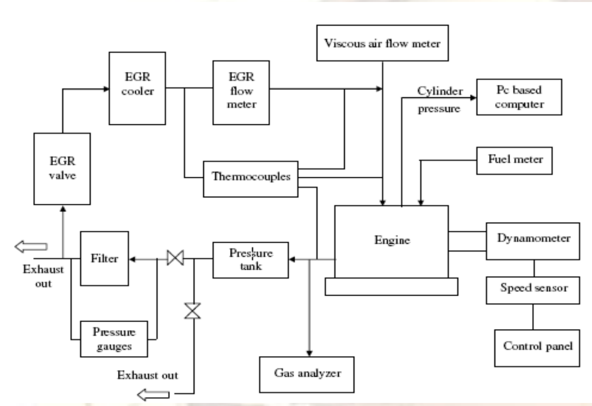

Fig.1.3 Schematic of the Experimental Test Rig

N. Saravanan et al., [5] used hydrogen-enriched air as intake charge in a diesel engine adopting exhaust gas recirculation (EGR) technique with hydrogen flow rate at 20 l/min. Experiments are conducted in a single cylinder, four stroke, water-cooled, direct-injection diesel engine coupled to an electrical generator. Performance parameters such as specific energy consumption, brake thermal efficiency are determined and emissions such as oxides of nitrogen, hydrocarbon, carbon monoxide, particulate matter, smoke and exhaust gas temperature are measured. Usage of hydrogen in dual fuel mode with EGR technique results in lowered smoke level, particulate and NO_X emissions.

Table 1.4 Technical Specifications of the Test Engine

Parameter	Specification
Bore	80 mm
Stroke	110 mm
Swept volume	553 cm^3
Clearance volume	36.87 cm^3
Compression ratio	16.5:1
Rated output	3.7KW at 1500 rpm
Rated speed	1500 rpm
Injection pressure	240 bar

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 NO_X emissions, while minimizing any negative impact on engine fuel economy and durability. An internal combustion engine having an exhaust gas recirculation (EGR) system reduces NO_X emissions while substantially maintaining fuel economy and durability. In many systems, for example, EGR is cooled to reduce NO_X emission levels at high engine loads. Systems in which EGR is not cooled may experience relatively high NO_X 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.

Fig.1.4 Development of EGR system

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 upto 10 minutes. After that we set the speed of engine as 800 rpm (Tachometer was used). Once rpm was set we observed time (by stopwatch) required by engine to consumed 20 ml 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, FC, SFC, BSFC, BTE, etc.) were calculated by obtained time and temperature.

The experiments was further carried out by setting speed of engine as 1000, 1200, 1400, 1600 rpm and time required by engine to consumed 20 ml 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.

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 is shown in Fig 1.5. 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 Fig.1.5 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 20 ml of fuel at various rpm), temperature, BP, SFC, BSFC, BTE, etc was same as that carried out for without EGR system.

Experimental Images:

Fig 1.5 Experimental Images

VII. RESULT AND DISCUSSION

Calculation

➢ **Without EGR System**

DATA:

Speed of Engine, N = 800 RPM
Weight, W = 3 kg = 3 × 9.81 = 29.43 N
Time t_f (time required by an engine to consume 20 ml of fuel at particular rpm of diesel) = 85 sec.
Calorific value, CV = 43000 kJ / kg
Radius of flywheel of engine, r = 0.5 meter (m)
Specific gravity = 0.82
Torque, T = W × r = 29.43 × 0.5 = 14.715 N-m

(1) Brake Power (B.P.):

$$\text{B.P.} = \frac{2\pi NT}{60} = \frac{2\pi\times800\times14.715}{60} = 1232.76\text{ W}$$

(2) Fuel Consumption (F.C.):

$$\text{F.C.} = \frac{20}{t_f}\times\frac{3600}{1000}\times specific\ gravity$$

$$= \frac{20}{85}\times\frac{3600}{1000}\times 0.82$$

F.C. = 0.6945 kg / hr

3) Specific Fuel Consumption (S.F.C.):

$$\text{S.F.C.} = \frac{F.C.}{B.P.} = \frac{0.6945}{1.232}$$

S.F.C. = 0.564 kg / kW hr

(4) Brake Specific Fuel Consumption (B.S.F.C.):
B.S.F.C. = S.F.C. × Calorific Value (C.V.)
= 0.564 × 43000
= 24252 kJ / kW hr

(5) Heat Supplied by Fuel (H.F.):
H.F. = F.C. × Calorific Value (C.V.)
= 0.6945 × 43000 = 29885 kJ / kg

(6) Brake Thermal Efficiency (B.T.E.):

$$\text{B.T.E.} \frac{B.P.\ in\ kWhr}{H.F.}\times 100$$

$$= \frac{1.232\times3600}{29885}\times 100 = 14.85\ \%$$

Table 1.5 Calculation (without EGR system):

Speed in RPM	Time in second	T in °C	B.P. in kW	F.C. in kg / hr	S.F.C. in kg / kW hr	B.S.F.C. in kJ / kW hr	H.F. in kJ / kg	B.T.E. in %
800	85	110	1.232	0.6945	0.564	24252	29885	14.85
1000	79	119	1.54	0.7473	0.485	20855	32121	17.25
1200	74	125	1.848	0.7978	0.431	18533	34271	19.39
1400	64	132	2.156	0.8682	0.428	18404	39689	20.78
1600	60	135	2.464	0.984	0.399	17157	42312	20.96

Where, B.P. = Brake Power
F.C. = Fuel Consumption
S.F.C. = Specific Fuel Consumption
B.S.F.C. = Brake Specific Fuel Consumption
H.F. = Heat Supplied by Fuel
B.T.E. = Brake Thermal Efficiency

VIII. Characteristics Performance Graph

(Without EGR system):

The variation of Exhaust Gas Temperature of the engine without EGR system at various Brake Power is shown in Figure 1.6. As shown in figure, when Brake power of the engine increases, Exhaust Gas Temperature of the engine also increases. The brake power of the engine varies from 1.232 kW to 2.464 kW and respectively Exhaust Gas Temperature varies from 110 °C to 135 °C.

The variation of fuel consumption of the engine without EGR system at various Brake Power is shown in Figure 1.7. As shown in figure, when Brake power of the engine increases, the fuel consumption of the engine is also increases. The brake power of the engine varies from 1.232 kW to 2.464 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 system at various Brake Power is shown in Figure 1.8. As shown in figure, 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 1.232 kW to 2.464 kW and respectively, brake thermal efficiency varies from 14.85 % to 20.96 %.

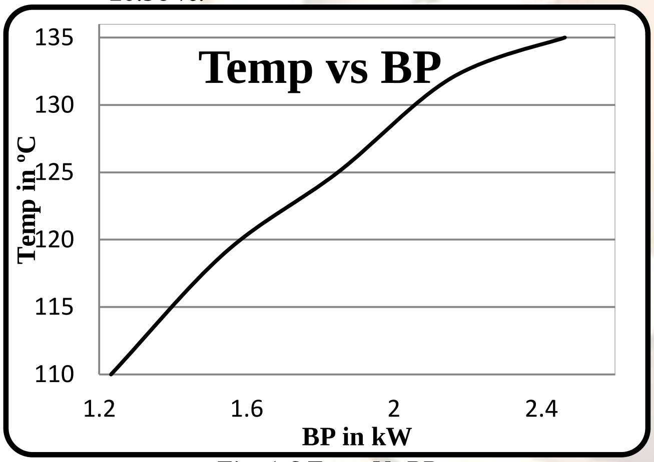

Fig. 1.6 Temp Vs BP

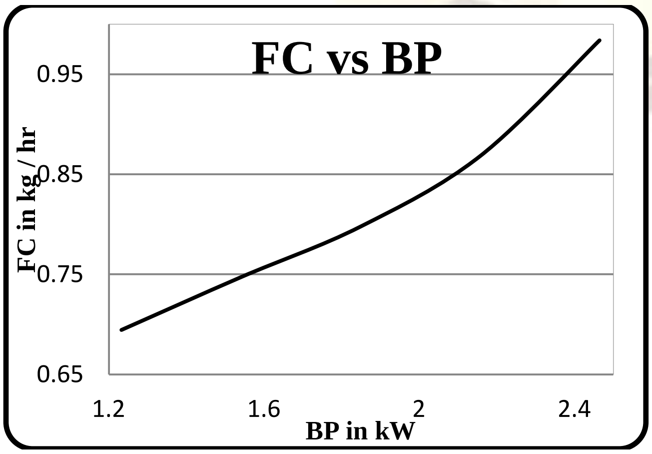

Fig. 1.7 FC Vs BP

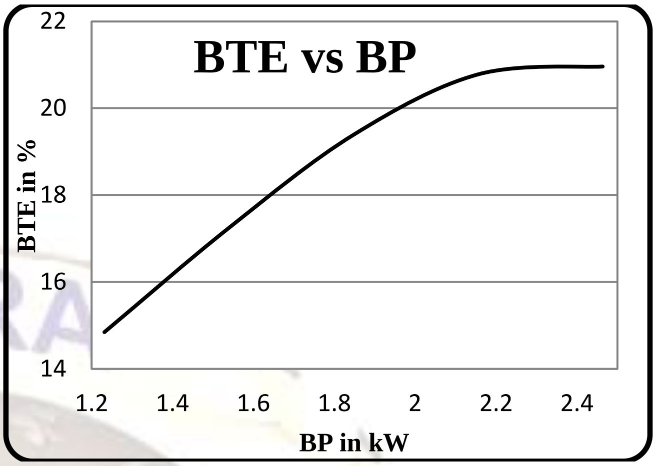

Fig. 1.8 BTE Vs BP

Emission Performance Graph (Without EGR System):

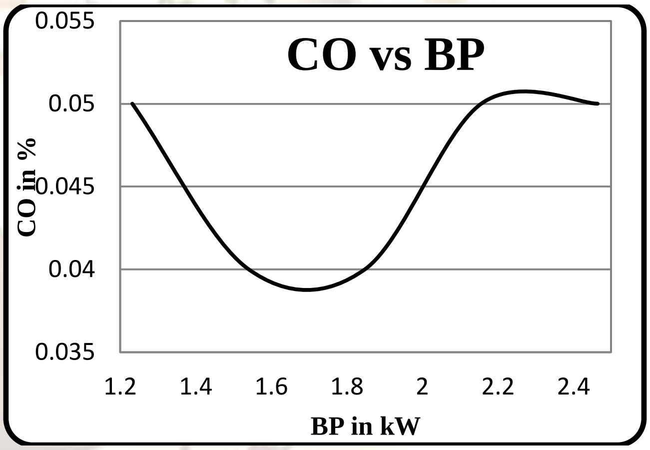

Fig. 1.9 CO Vs BP

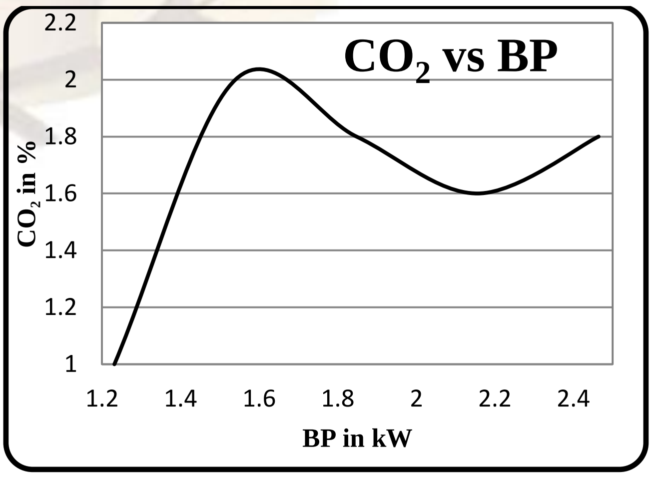

Fig. 2.1 CO_2 Vs BP

Table 1.6 Emission (without EGR system):

Speed in RPM	Time in Sec.	Temp. in °C	B.P. in KW	CO	CO_2	NO_x	HC
800	85	110	1.232	0.05	1	759	18.5
1000	79	119	1.54	0.04	2	765	18
1200	74	125	1.848	0.04	1.8	769	18
1400	64	132	2.156	0.05	1.6	775	17
1600	60	135	2.464	0.05	1.8	782	16.4

The variation of Carbon Monoxide (CO) of the engine without EGR system at various Brake Power is shown in Figure 1.9. 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 figure 1.9 as brake power of the engine varies from 1.232 kW to 2.464 kW and Carbon Monoxide (CO) varies from 0.04 % to 0.05 %.

The variation of Carbon Dioxide (CO2) of the engine without EGR system at various Brake Power is shown in Figure 2.1. As shown in figure, 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 1.232 kW to 2.464 kW and Carbon Dioxide (CO2) varies from 1 % to 2 %.

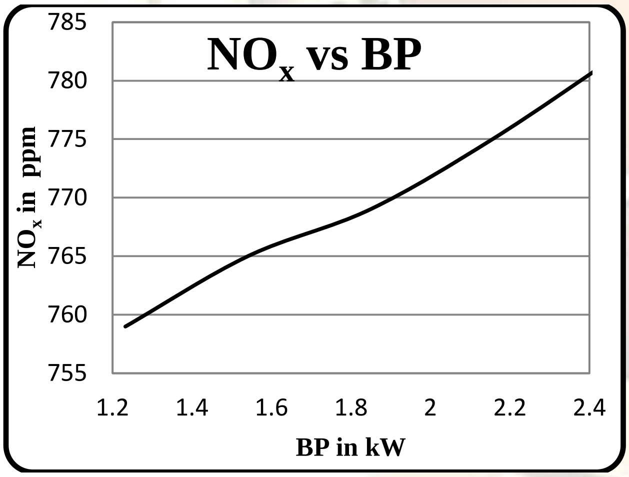

Fig. 2.2 NO_x Vs BP

The variation of Nitrogen Oxide (NO_x) of the engine without EGR system at various Brake Power is shown in Figure 2.2. As shown in figure, when Brake power of the engine increases, Emission of Nitrogen Oxide (NO_x) of the engine also increases. The brake power of the engine varies from 1.232 kW to 2.464 kW and Emission of Nitrogen Oxide (NO_x) varies from 759 ppm to 782 ppm.

IX. Calculation

(With EGR System):

DATA:

Speed of Engine, N = 800 RPM
Weight, W = 3 kg = 3 × 9.81 = 29.43 N
Time t_f (time required by an engine to consume 20 ml of fuel at particular rpm of diesel) in sec.
Calorific value, CV = 43000 kJ / kg
Radius of flywheel of engine, r = 0.5 meter (m)
Specific gravity = 0.82
Torque, T = W × r = 29.43 × 0.5 = 14.715 N-m

(1) Brake Power (B.P.):

$$\text{B.P.} = \frac{2\pi NT}{60} \quad \frac{2\pi \times 800 \times 14.715}{60} =$$

$$= 1232.76 \text{ W}$$

B.P. = 1.232 kW

(2) Fuel Consumption (F.C.):

$$\text{F.C.} = \frac{20}{t_f} \times \frac{3600}{1000} \times specific\ gravity$$

$$= \frac{20}{81} \times \frac{3600}{1000} \times 0.82 = 0.7288 \text{ kg / hr}$$

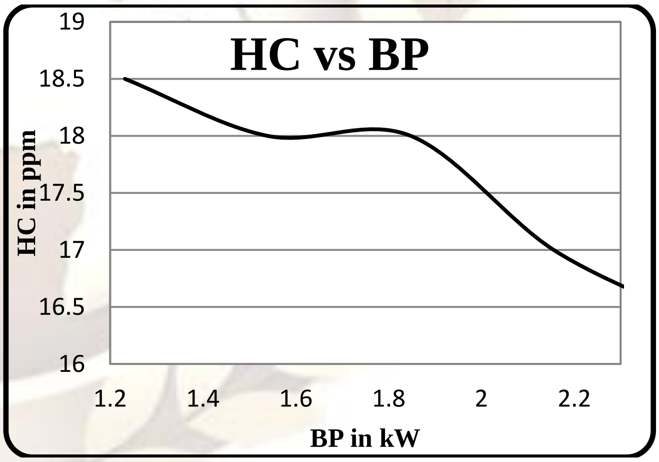

Fig. 2.3 HC Vs BP

The variation of Hydro Carbon (HC) of the engine without EGR system at various Brake Power is shown in Figure 2.3. As shown in figure, when Brake power of the engine increases, Emission of Hydro Carbon (HC) of the engine decreases. The brake power of the engine varies from 1.232 kW to 2.464 kW and Emission of Hydro Carbon (HC) varies from 18.5 ppm to 16.4 ppm.

3) Specific Fuel Consumption (S.F.C.):

S.F.C. = $\frac{F.C.}{B.P.}$

$= \frac{0.7288}{1.232}$

S.F.C. = 0.592 kg / kW hr

(4) Brake Specific Fuel Consumption (B.S.F.C.):

B.S.F.C. = S.F.C. × Calorific Value (C.V.)
= 0.592 × 43000
= 25456 kJ / kW hr

(5) Heat Supplied by Fuel (H.F.):

H.F. = F.C. × Calorific Value (C.V.)
= 0.7288 × 43000
H.F. = 31347 kJ / kg

(6) Brake Thermal Efficiency (B.T.E.):

B.T.E. = $\frac{B.P.\ in\ kWhr}{H.F.} \times 100$

$= \frac{1.232 \times 3600}{31347} \times 100$

B.T.E. = 14.15 %

Table 1.7 Calculation (with EGR system)

Speed in RPM	Time in second	Temperature in °C	B.P. in kW	F.C. in kg / hr	S.F.C. in kg / kW hr	B.S.F.C. in kJ / kW hr	H.F. in kJ / kg	B.T.E. in %
800	81	105	1.232	0.7288	0.592	25456	31347	14.15
1000	70	115	1.54	0.8435	0.547	23521	36249	15.28
1200	63	119	1.848	0.9371	0.507	21801	40291	16.5
1400	55	125	2.156	1.0357	0.497	21371	46139	17.42
1600	50	129	2.464	1.1808	0.479	20597	50740	17.47

B.P. = Brake Power
F.C. = Fuel Consumption
S.F.C. = Specific Fuel Consumption
B.S.F.C. = Brake Specific Fuel Consumption
H.F. = Heat Supplied by Fuel
B.T.E. = Brake Thermal Efficiency

Characteristics Performance Graph (With EGR system):

The variation of Exhaust Gas Temperature of the engine with EGR system at various Brake Power is shown in Figure 2.4. As shown in figure, when Brake power of the engine increases, Exhaust Gas Temperature of the engine also increases. The brake power of the engine varies from 1.232 kW to 2.464 kW and Exhaust Gas Temperature varies from 105 °C to 129 °C.

The variation of fuel consumption of the engine with EGR system at various Brake Power is shown in Figure 2.5. As shown in figure, when Brake power of the engine increases, fuel consumption of the engine also increases. The brake power of the engine varies from 1.232 kW to 2.464 kW and fuel consumption varies from 0.7288 kg/hr to 1.1808 kg/hr.

The variation of the brake thermal efficiency of the engine with EGR system at various Brake Power is shown in Figure 2.6. As shown in figure, when Brake power of the engine increases, Brake thermal efficiency of the engine also increases. The brake power of the engine varies from 1.232 kW to 2.464 kW and Brake thermal efficiency varies from 14.15% to 17.47%.

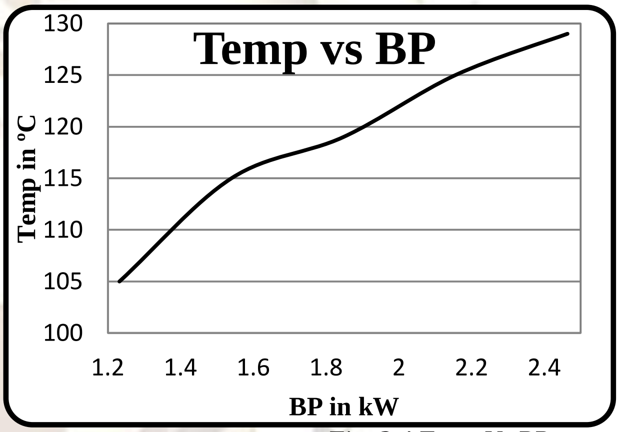

Fig. 2.4 Temp Vs BP.

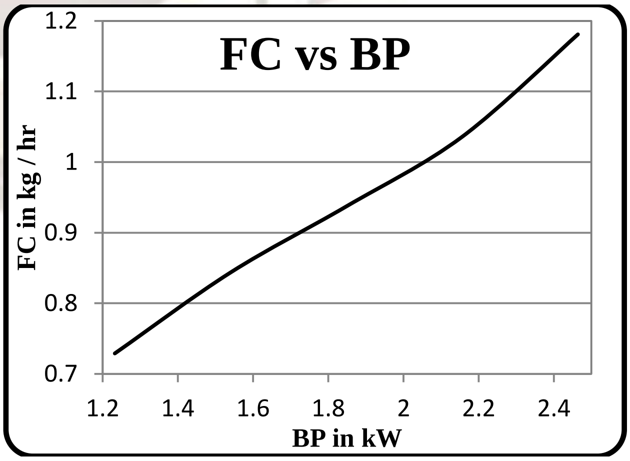

Fig. 2.5 FC Vs BP

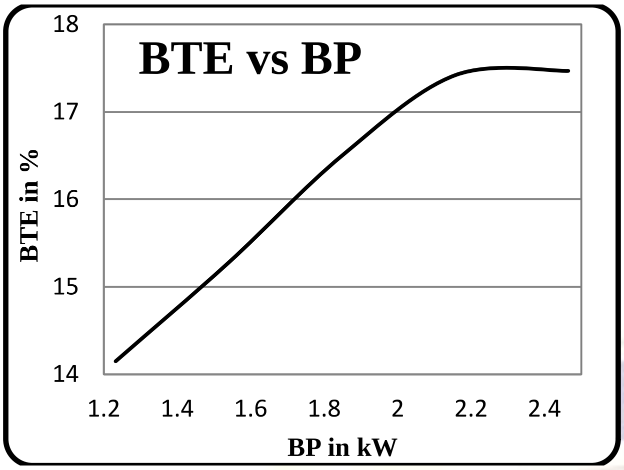

Fig. 2.6 BTE Vs BP

Table 1.8 Emissions (EGR System):

Speed in RPM	Time in Sec.	Temp. in °C	B.P. in kW	CO	CO_2	NO_X	HC
800	81	105	1.232	0.04	0.9	731	19.5
1000	70	115	1.54	0.04	1	742	18.6
1200	63	119	1.848	0.03	0.8	748	17.9
1400	55	125	2.156	0.03	0.8	756	17.2
1600	50	129	2.464	0.04	1	764	17.0

X. Emission Performance Graph With EGR system:

The variation of Carbon Monoxide (CO) of the engine with EGR system at various Brake Power is shown in Figure 2.7. As shown in figure, 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 1.232 kW to 2.464 kW and Emission of Carbon Monoxide (CO) varies from 0.03 % to 0.04 %.

The variation of Emission of Carbon Dioxide (CO_2) of the engine with EGR system at various Brake Power is shown in Figure 2.8. As shown in figure, when Brake power of the engine increases, Emission of Carbon Dioxide (CO_2) of the engine also increases. The brake power of the engine varies 1.232 kW to 2.464 kW and Emission of Carbon Dioxide (CO_2) varies from 0.8 % to 1 %.
The variation of Nitrogen Oxide (NO_x) of the engine with EGR system at various Brake Power is shown in Figure 2.9. As shown in figure, when Brake power of the engine increases, Emission of Nitrogen Oxide (NO_x) of the engine also increases.
The brake power of the engine varies from 1.232 kW to 2.464 kW and Emission of Nitrogen Oxide (NO_x) varies from 731 ppm to 764 ppm.

The variation of Emission of Hydro Carbon (HC) of the engine with EGR system at various Brake Power is shown in Figure 3.1. As shown in figure, 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 1.232 kW to 2.464 kW and Emission of Hydro Carbon (HC) varies from19.5 ppm to 17 ppm.

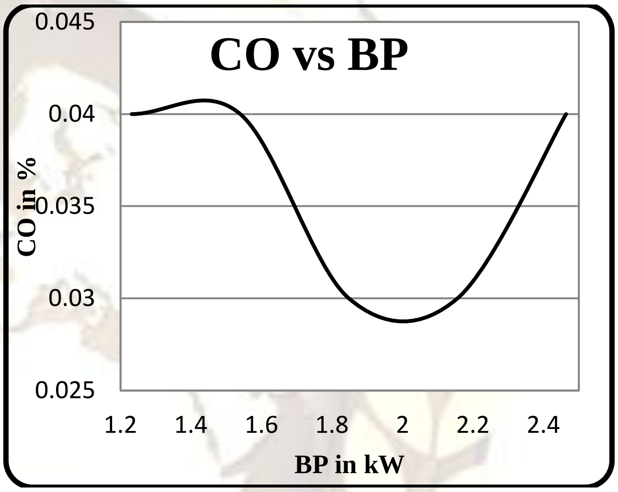

Fig. 2.7 CO Vs BP

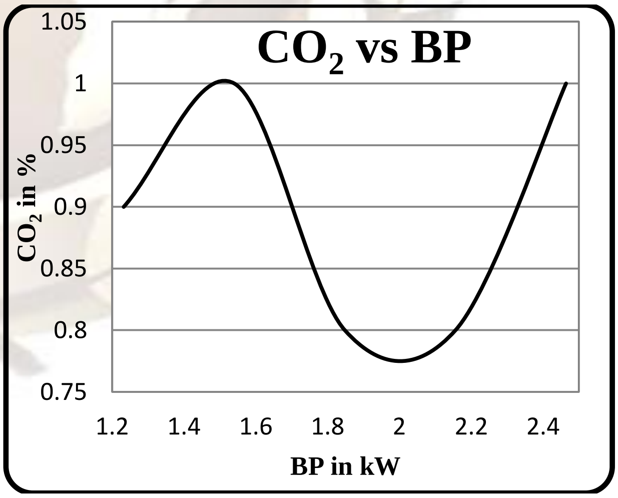

Fig. 2.8 CO_2 Vs BP

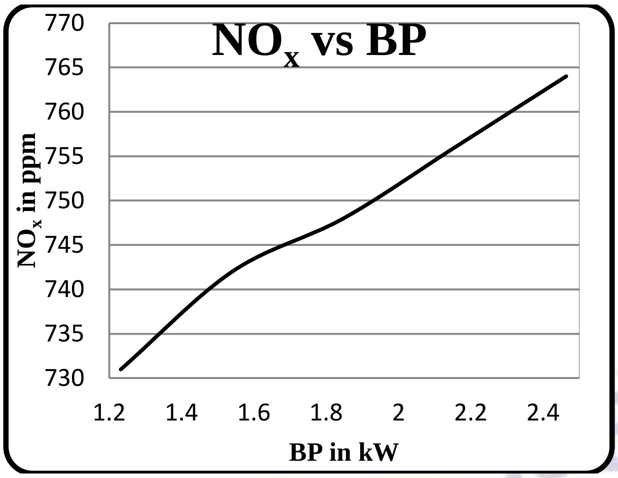

Fig. 2.9 NO_x Vs BP

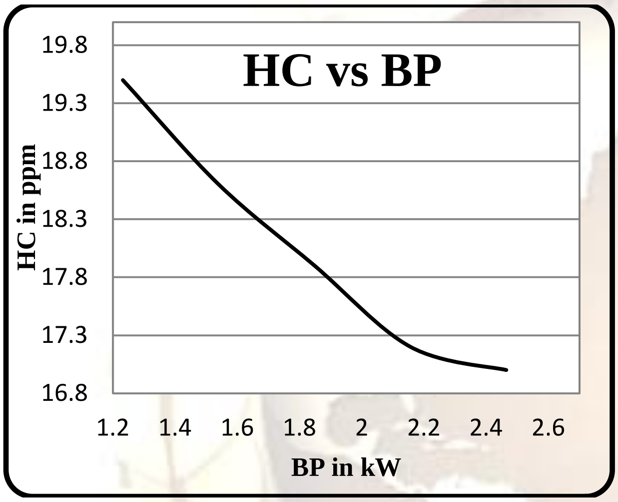

Fig. 3.1 HC Vs BP

XI. Comparison Graph

(With & without EGR system)

Figure 3.2 shows Comparison graph of with and without EGR system of variation in Temperature 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.

Figure 3.3 shows Comparison graph of with and without EGR system of variation in Fuel Consumption 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.

Figure 3.4 shows Comparison graph of with and without EGR system of variation in Fuel Consumption 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.

Figure 3.5 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 3.6 shows Comparison graph of with and without EGR system of variation in Emission of CO_2 with respect to Brake Power. From the above figure it is clear that the value of Emission of CO_2 of the diesel engine with EGR is less than that of without EGR system at same brake power.

Figure 3.7 shows Comparison graph of with and without EGR system of variation in Emission of NO_x with respect to Brake Power. From the above figure it is clear that the value of Emission of NO_x of the diesel engine with EGR is less than that of without EGR system at same brake power

Figure 3.8 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.

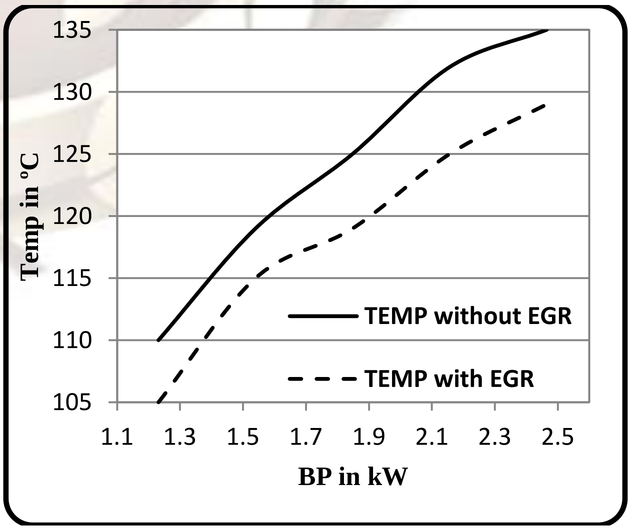

Fig. 3.2 Temp Vs BP

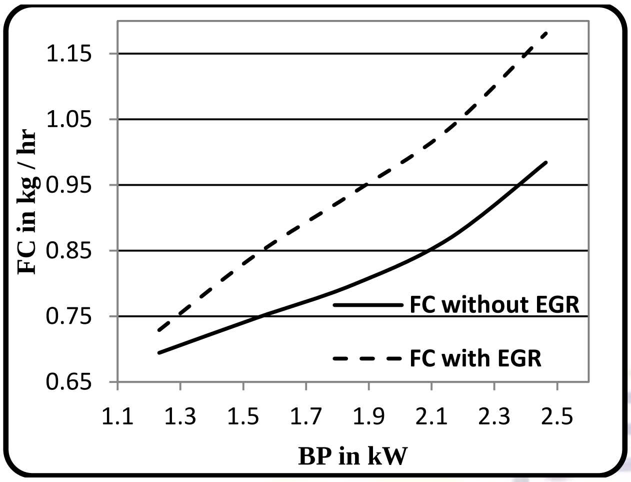

Fig. 3.3 FC Vs BP

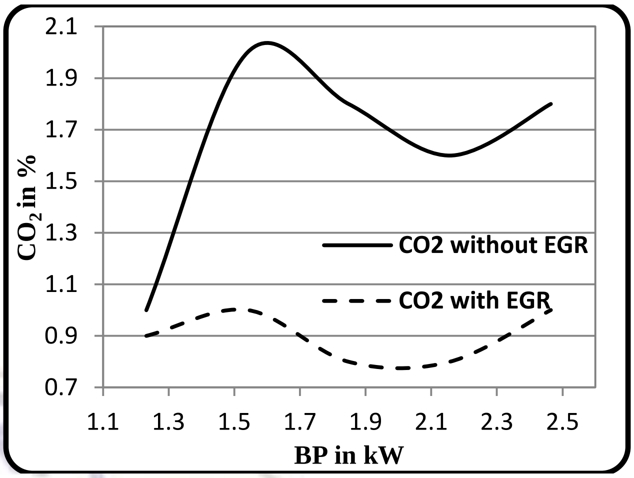

Fig. 3.6 CO_2 Vs BP

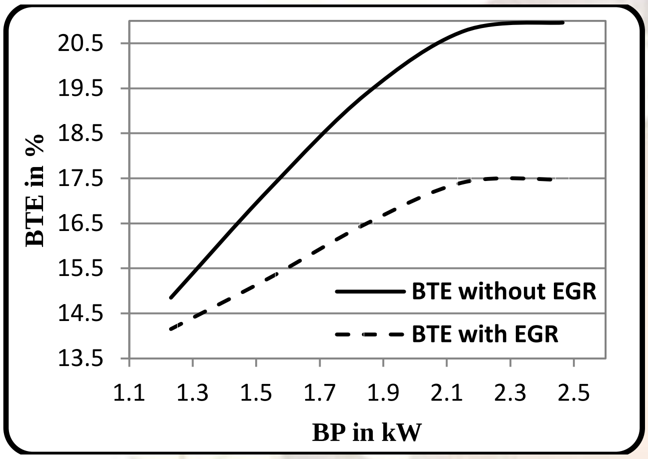

Fig. 3.4 BTE Vs BP

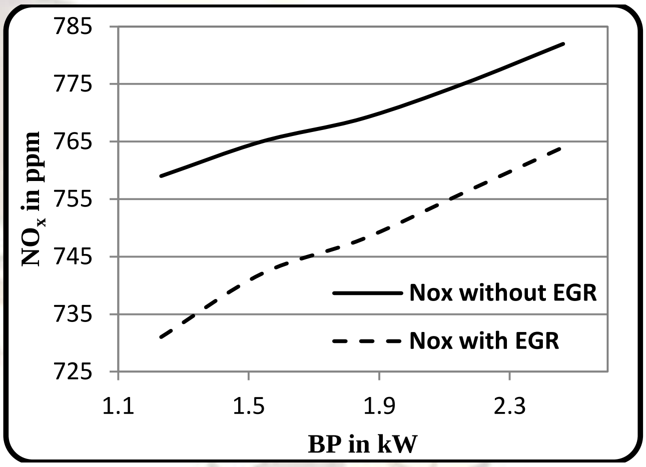

Fig. 3.7 NO_x Vs BP

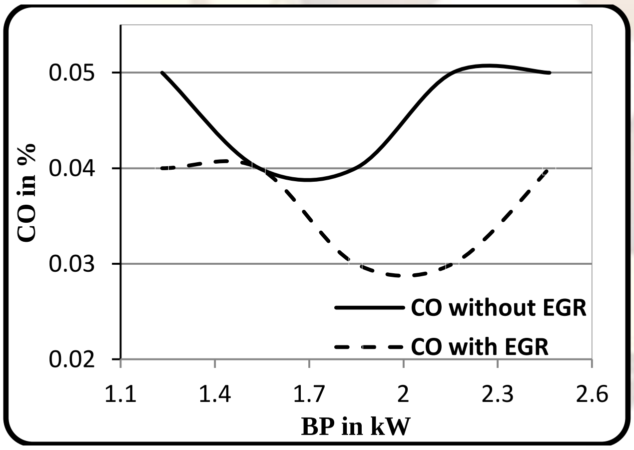

Fig. 3.5 CO Vs BP

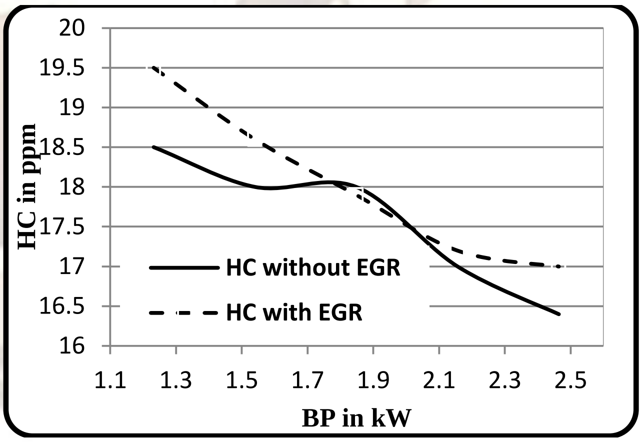

Fig. 3.8 HC Vs BP

XII. 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.
- Figure 3.4 shows Comparison graph of with and without EGR system of variation in Fuel Consumption 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.

- 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 (NO_x) was very much reduced by implementation of EGR system.
- Emission of Carbon Dioxide (CO_2) 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.

XIII. FUTURE SCOPE

Exhaust Gas Recirculation system advantageous for environment

- Further work in same project can be done for measurement of inlet air flow and exhaust air flow and percentage flow of EGR can be calculated and optimum value of EGR rate can be used for practical use.
- Biodiesel contain more sulphur and lead, while using biodiesel in engine it produces more emission in surrounding due to sulphur and lead. As EGR system reduces the emission rate, Biodiesel can be used as fuel in engines.

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NOMENCLATURE

FC	Fuel Consumption
SFC	Specific Fuel Consumption
HF	Heat Supplied by Fuel
BSFC	Brake Specific Fuel Consumption
BTE	Brake Thermal Efficiency
BP	Brake power
IC ENGINE	Internal Combustion Engine
EGR	Exhaust Gas Recirculation
CO	Carbon Monoxide
CO2	Carbon Dioxide
NOX	Oxides of Nitrogen
HC	Hydrocarbon
ºC	Degree Celsius
CV	Calorific Value
kW	Kilo Watt
hr	Hour
HC	Hydro Carbon
ppm	Parts per million
Vs	Versus
%	Percentage
RPM	Revolutions per Minute
EGT	Exhaust