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ANALYSIS OF EXHAUST GAS RECIRCULATION (EGR) SYSTEM

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ABSTRACT

Exhaust gas recirculation (EGR) is a way to control in-cylinder NOx and carbon production and is used on most modern high-speed direct injection (HSDI) diesel engine. However EGR has different effects on combustion and emissions production that are difficult to distinguish increase of intake temperature, delay of rate of heat release (ROHR), decrease of peak heat release, decrease in O2 concentration and thus of global air/fuel ratio (AFR) and flame temperature, increase of lift-off length etc. Prevailing and future emission norms compel engine manufacturers to incorporate techniques to reduce engine out emissions especially NOX and particulate matter NOx formation predominantly depends on high combustion temperature and literature indicates EGR is an attractive method to reduce combustion temperature. EGR temperature is an important factor while admitting higher percentage of EGR. Higher EGR temperatures caused due to increased loads limit the conduct of higher EGR ratios. EGR cooling can be advantageous when higher ratios of EGR need to be employed. The effect EGR temperature on engine thermal efficiency, NOx, smoke and HC emissions at different load conditions are discussed in this paper. NOx reductions and thermal efficiency were found to be better. Smoke and HC emissions increase for cooled EGR as compared to no EGR case.

Keywords: *Exhaust gas recirculation; combustion; Heat release; Pollutant emission; NOx emission decrease.*

I.INTRODUCTION

Future regulation like EURO 5 and presumably 6 will force diesel engine manufacturers to drastically reduce NOx and particulate matter (PM) emissions. External exhaust gas recirculation (EGR) is a well-known in-cylinder method to reduce NOx emissions, particularly on modern direct injection (DI) automotive diesel engine, and offers the possibility to decrease temperature during combustion. The decrease in NOx emissions with the increase of EGR rate is the result of various effects:

The thermal effect: Increase of inlet heat capacity due to higher specific heat capacity of recirculated CO2 and H2O compared with O2 and N2 (at constant boost pressure) resulting in lower gas temperature during combustion, and particularly in a lower flame temperature In order to better understand the effects of a reduction of in in-cylinder gas concentration oxygen flame development and combustion when EGR is used to reduce NOx emissions Siebers and co-workers have studied typical DI diesel sprays with a single-hole common-rail injector mounted on a constant volume quiescent combus- tion vessel. They showed that the location of flame lift-off on diesel fuel jet plays an important role in combustion and emissions processes, by allowing fuel and air to mix upstream of the lift-off length (i.e. prior to any combus- tion). Just downstream of the lift-off length, the partially- premixed air–fuel mixture is undergoing a premixed combustion that generates a significant local heat release and a fuel-rich product gas that becomes the ‘‘fuel’’ for the diffusion flame at the jet periphery. The soot formation was shown to be directly dependent on the equivalent fuel–air ratio at the lift-off length; no soot would be produced when it is lower than approximately . Another important result is the following: the lift-off length is inversely proportional to the ambient gas oxygen concentration. Thus, when reducing ambient gas oxygen concentration, the total amount of gases entrained in the spray upstream of the lift-off length increases that compensates for the reduction in oxygen concentration, so that the total amount of oxygen entrained in the premixed mixture does not change. These observations made the authors to propose a new LTC concept, the so-called ‘‘non-sooting, low-flame-temperature mixing-controlled combustion’’ that consists in promoting the air–fuel mixing before the lift-off length (thanks to very small injector holes) and dramatically reducing the combustion temperature with the use of high EGR rates.

II.LITERATURE REVIEW

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. 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 co

mbustion rate and significant reduction in peak pressure at maximum load.

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Technical Specification of engine

Parameter	Specification
Bore × Stroke	80mm x 110mm
Displacement volume	553 cm3
Compression ratio	16.5:1
Type of cooling	Water cooled
Rated power	3.7KW @ 1500rpm

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), 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.

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

Technical specification of engine

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 (NOX), 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 NOX 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 NOX emissions can be attained within a limited EGR rate of 5–15% with very little economy penalty.

III.EXPERIMENTAL SETUP & METHODOLOGY

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

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, directinjection 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 NOX emissions.

Parameter	Specification
Bore	80 mm
Stroke	110 mm
Swept volume	553 cm3
Clearance volume	36.87 cm3
Rated output	3.7KW at 1500 rpm
Rated speed	1500 rpm
Compression ratio	16.5:1
Injection pressure	240 bar

Technical specification of test engine

IV.DEVELOPMENT OF EGR SYSTEM

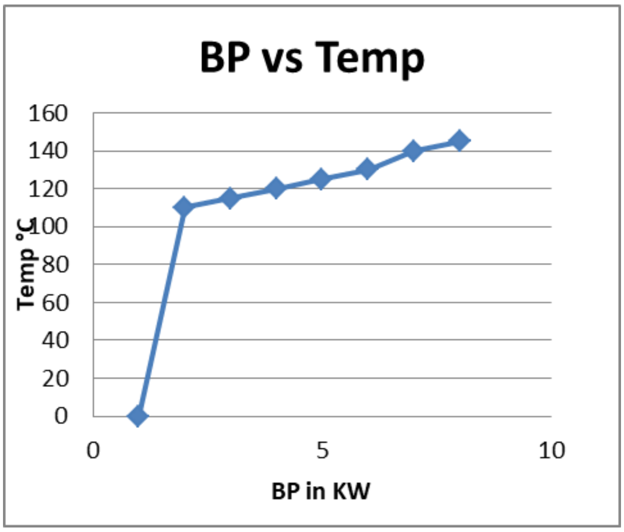
Increased demands are being placed on engine manufacturers to design and build engines that provide better engine performance, improved reliability and greater durability while meeting more stringent emission and noise requirements. One important object for internal combustion engine designers is to 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.

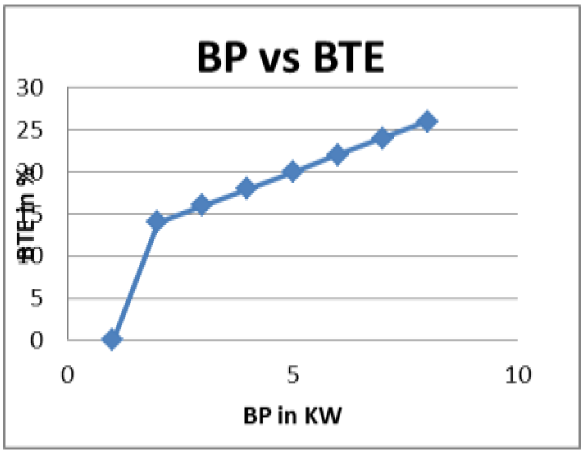
V.EXPERIMENTAL PROCEDURE

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.

VI.CHARACTERISTICS PERFORMANCE GRAPH

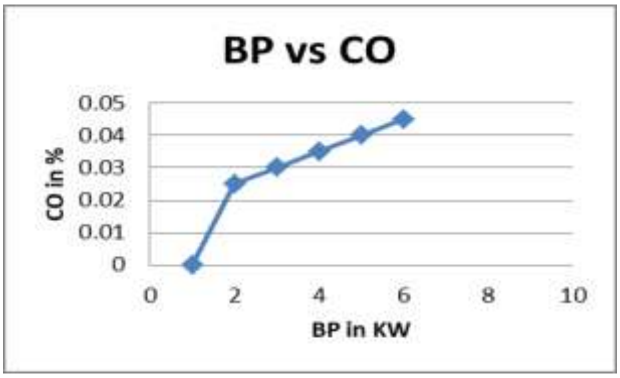
(Without EGR system):

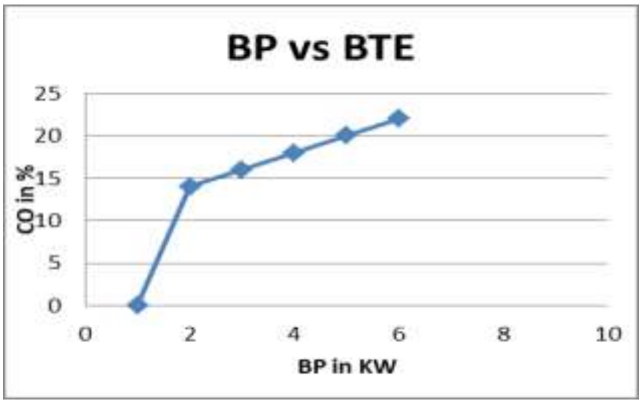




VII.EMISSION PERFORMANCE GRAPH

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 (CO2) 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 (CO2) of the engine also increases. The brake power of the engine varies 1.232 kW to 2.464 kW and Emission of Carbon Dioxide (CO2) varies from 0.8 % to 1 %. The variation of Nitrogen Oxide (NOx) 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 (NOx) 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 (NOx) 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





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:

1. The engine performance on EGR system, Exhaust Gas Temperature reduces as compared to that of without EGR system, so it is beneficial for surrounding
2. 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
3. Emission of Oxide of Nitrogen (NOx) was very much reduced by implementation of EGR system.
4. Emission of Carbon Dioxide (CO2) and Carbon Mono-oxide (CO) was also reduced
5. Emission of Hydro Carbon (HC) increases by implementing EGR system with engine than that of operating engine without EGR system

IX.FUTURE SCOPE

Exhaust Gas Recirculation system advantageous for environment

1. 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.
2. 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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