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Experimental Investigation of Performance and Emission Characteristics by Different Exhaust Gas Recirculation Methods used in Diesel Engine

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Abstract - This project aims at the experimental investigation of the effects of hot and cold Exhaust gas recirculation (EGR) methods on emissions and efficiency of the engine. This experiment is conducted in single cylinder, 4-stroke, direct injection diesel engine. A heat exchanger arrangement is provided for obtaining different EGR methods. The performance parameters were studied with and without exhaust gas recirculation of different methods with 10%, 15% and 20% of EGR. The recycled exhaust gas lowers the oxygen concentration in the combustion chamber and increases the temperature of intake charge which lowers the flame temperature and leads to lower NO_x formation. Experimental results shows that the cold EGR is much effective than the hot and intermediate EGR for the reduction of NO_x emission. The increase in temperature of EGR gases causes the combustion temperature which leads to increase in formation of NO_x. By increasing the cooled EGR rates reduces the emissions more significantly.

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EXPERIMENTAL INVESTIGATION OF PERFORMANCE AND EMISSION CHARACTERISTICS BY DIFFERENT EXHAUST GAS RECIRCULATION METHODS USED IN DIESEL ENGINE

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R. Senthilkumar [α], K. Ramadoss [σ] & R.Manimaran [ρ]

Abstract - This project aims at the experimental investigation of the effects of hot and cold Exhaust gas recirculation (EGR) methods on emissions and efficiency of the engine. This experiment is conducted in single cylinder, 4-stroke, direct injection diesel engine. A heat exchanger arrangement is provided for obtaining different EGR methods. The performance parameters were studied with and without exhaust gas recirculation of different methods with 10%, 15% and 20% of EGR. The recycled exhaust gas lowers the oxygen concentration in the combustion chamber and increases the temperature of intake charge which lowers the flame temperature and leads to lower NO_x formation. Experimental results shows that the cold EGR is much effective than the hot and intermediate EGR for the reduction of NO_x emission. The increase in temperature of EGR gases causes the combustion temperature which leads to increase in formation of NO_x. By increasing the cooled EGR rates reduces the emissions more significantly.

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I. Introduction

The compression ignition engines are widely used owing to its high thermal efficiency and low maintenance cost. In spite of all these benefits, diesel engine exhaust is one of the major sources of atmospheric pollution in the world, accounting for about 60% of the total pollutants dumped into the atmosphere. UBHC, CO, NO, etc., are the major constituents of the engine exhaust pollutants and efforts are throughout the world to find effective means to control them. Thus the fields of diesel fuel alternative and diesel emission control are alive. A Diesel engine is a type of heat engine that uses the internal combustion process to convert the energy stored in the chemical bonds of the fuel into useful mechanical energy[1][4,7,9]. This occurs in two steps. First; the fuel reacts chemically (burns) and releases energy in the form of heat. Second the heat Causes the gases trapped in the cylinder must move piston to expand. The reciprocating motion of the piston is then converted into rotational motion by the crankshaft. Then the fuel enters the cylinder where the heated compressed air is present; however, it will only burn when it is in a vaporized state and intimately mixed with the supply of oxygen. The first minute droplets of fuel enter the combustion chamber and are quickly vaporized. The vaporization of the fuel causes the air surrounding the fuel to cool and it requires time for air to reheat sufficiently to ignite the vaporized fuel. But once ignition has started, the addition heat from combustion helps to further vaporize the new fuel entering the chamber as long as oxygen is present. Engine deposits constitute a serious problem in the compression-ignition engine. Solid or semisolid carbonaceous matter builds up because of incomplete combustion. The compression-ignition engine exhaust gases contain Oxides of Nitrogen, carbon monoxide, organic compounds that are unburned or partially burned or partially burnt hydrocarbons, visible smoke and soot (or particulates).

a) Literature Review

Alain Maiboom [1] has studied the effect of exhaust gas recirculation in direct injection diesel engine. The experimental results shows that the increase of inlet temperature at constant EGR rate has contrary effects on combustion and emissions, thus sometimes giving opposite tendencies as traditionally observer, as the reduction of NO_x emissions with increased inlet temperature. At low-load conditions, very low-NOx and particulate matter emissions can be obtained with high EGR rates at constant pressure, because the combustion is delayed due to the high dilutions. This is accompanied with an increase of BSFC, CO and hydrocarbon emissions. For some operating conditions, EGR at constant AFR is a way to drastically reduce NO_x emissions without important penalty on BSFC and soot emissions. S.Swami Nathan [2] as investigated the possibility to operate a HCCI engine with reasonably high thermal efficiencies in a

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wide range of BMEP's with acetylene as the sole fuel. The intake charge temperature and amount of EGR have to be controlled based on output of engine thus leads to low NO emissions and smoke. At high BMEP's the hot EGR leads to knock, it can be avoided by proper control over the temperature and amount of re-circulated exhaust. P.V.Walke [3] have done the experimental investigation on the impact of exhaust gas recirculation on the diesel engine performance and observed that with increasing rates of EGR at different torque there is a marginal decrease in brake thermal efficiency. Increase in EGR the concentration of NOx decreases. M.Gomaa [4] studied the effects of EGR rates on diesel engine and shows that the CO emissions increased with various EGR rate. The possible reason may be lower excess oxygen available for combustion. Lower excess oxygen results in rich air fuel mixture at different locations inside the combustion chamber. The NO in combustion chamber is reduced due to higher pressure and higher temperatures during combustion. L.Niranjan [5, 11] has done an experimental investigation on the effects of cold and hot EGR using bio-diesel as fuel. From their result they conclude the NOx emission is increased due to increase in temperature of the EGR gases causes the combustion temperature to increase, as well as causing the combustion gases to spend longer periods at higher temperatures. Hatim Machrafi [6] have numerically investigated the influence of EGR on the HCCI engine. They have studied the effect of CO on the auto ignition process. Regarding the effect of CO on this study suggest that CO can be either promote or inhibit auto ignition delay. V.Pradeep and R.P.Sharma [7,12] investigates the use of HOT EGR for NOx control in a C.I engine fuelled with bio-diesel. Full load NO emission from bio-diesel with EGR, was found lower than that of without EGR and it shows that the BTE was found to be comparable with and without EGR at all loads.

Hitoshi Yokomura, Koji mori [8,9] studied Expansion of EGR Area with Venturi EGR System the application. The application of EGR to diesel engines achieves larger reductions in NOx emissions under a high load condition than a low-load condition for the same EGR rate. In other words, under the high-load condition, a low EGR rate produces the same NOx emission reduction effect as a high EGR rate under the low-load condition[10]. The venturi EGR system expands the EGR-feasible range without adversely affecting fuel economy caused by an increase of pumping loss, and it is thus an effective system for turbocharged diesel engines.

II. Methodology

The test engine is a single cylinder, direct injection, water cooled Compression Ignition engine. The experimental setup is shown in fig.1. An orifice box is connected to the inlet manifold and the air mass flow rate is measured using the manometer connected to the orifice box.

The EGR system consists of a piping system taken from the engine exhaust pipe, and an orifice meter to used measure the flow rate of the exhaust gases and a control valve. The amount of exhaust gas recycling into the inlet manifold is controlled by means of two valves, one in the inlet pipe and other in the pipe line connecting the exhaust line and the inlet manifold.

The re-circulated exhaust gas flows through another orifice meter with inclined manometer for measuring the flow rate, before mixing with the fresh air. Cold EGR is attained by cooling the re-circulated exhaust gas. The exhaust gas recirculation line is connected to a parallel flow heat exchanger having water as the cold fluid. Thermometers are connected to inlet and exit of the cold and hot fluids in the heat exchanger.

The probe of exhaust gas analyzer is inserted into the exhaust pipe for emission measurement. The engine is loaded using rope brake dynamometer. The load on the engine is noted down. The photographs of experimental setup are shown in appendix.

a) Texvel Engine Specifications

Type : single cylinder ,four stroke cycle, vertical engine

Bore in mm	-	85
Stroke in mm	-	110
Rated RPM	-	1500
Rated power output in kW	-	6.5
Loading	-	Rope braking
Connecting rod length	-	235mm
Compression ratio	-	18:1
Rated speed	-	1500 rpm
Orifice diameter	-	0.016

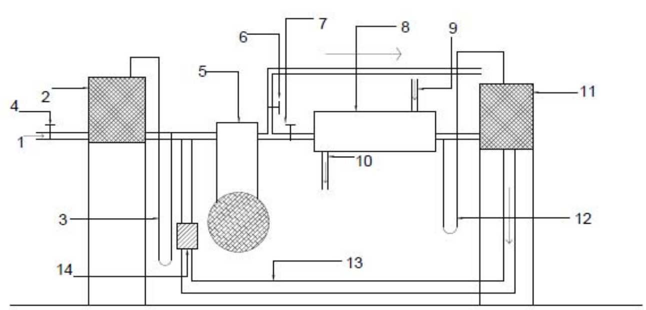

Figure 1 : Schematic Diagram of Experimental setup

1. Air inlet
2. Air inlet Orifice box
3. Air inlet manometer
4. Air inlet control valve
5. CI engine
6. Exhaust gas control valve

7. EGR control valve
8. Heat exchanger
9. Water inlet
10. Water outlet
11. Exhaust gas Orifice box
12. Exhaust gas manometer
13. EGR pipe
14. Particulate filter

III. Results and Discussion

Performance and emission tests were carried out with and without exhaust gas recirculation of different methods of 10%, 15%, 20% and 25% of EGR. The tests are conducted at the rated speed of 1500 rpm at various loads. Based on the experimental data the graphs were drawn. These graphs show the variation of specific fuel consumption, mechanical efficiency, Brake thermal efficiency, Indicated power, BMEP and IMEP with respect to Brake power for various percentages and methods of EGR.

Specific fuel consumption is found to be high at all loads with and without EGR. Brake thermal efficiency with 10% EGR was comparable without EGR at all loads. Indicated thermal efficiency with cold EGR is better as compared with hot and intermediate EGR but it relatively low without EGR. NO_x emission from hot EGR is comparatively higher than without EGR. Cold EGR of higher rates shows much effective in reducing NO_x emission.CO2 emission at 10% cold EGR percentages is very high than that of higher EGR rates.CO emissions with EGR was increased in part loads and decreases with higher loads as compared without EGR.

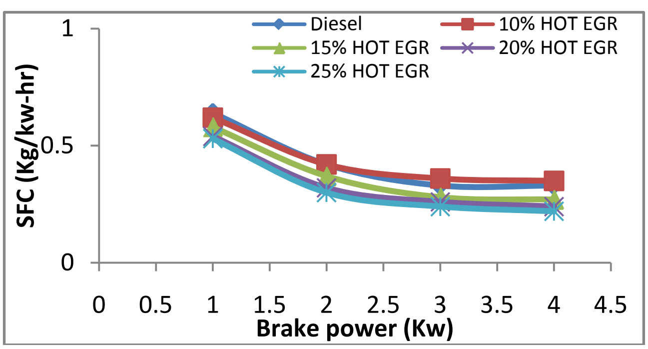

Figure 1 : BP Vs SFC for various hot EGR ratios

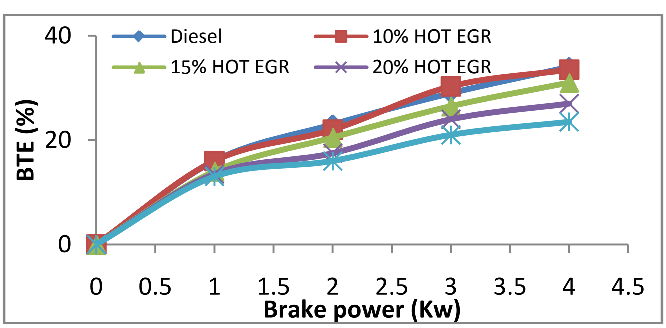

Figure 2 : BP Vs BTE for various hot EGR ratios

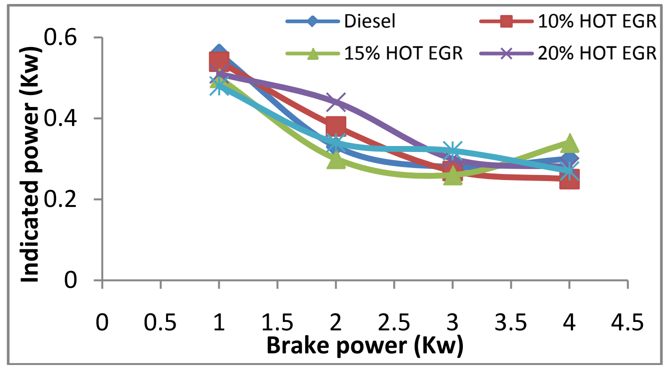

Figure 3 : BP Vs IP for various cold EGR ratios

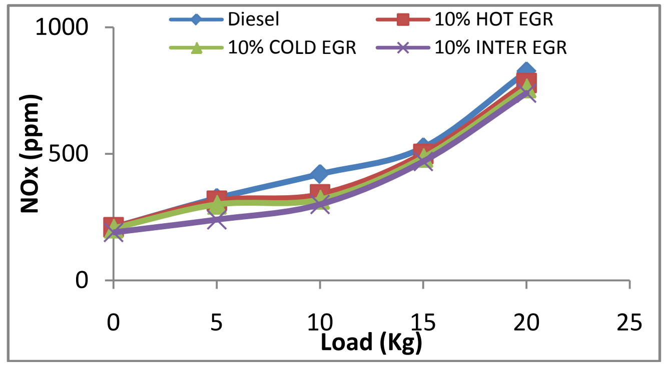

Figure 4 : LOAD Vs NO_x for 10% EGR

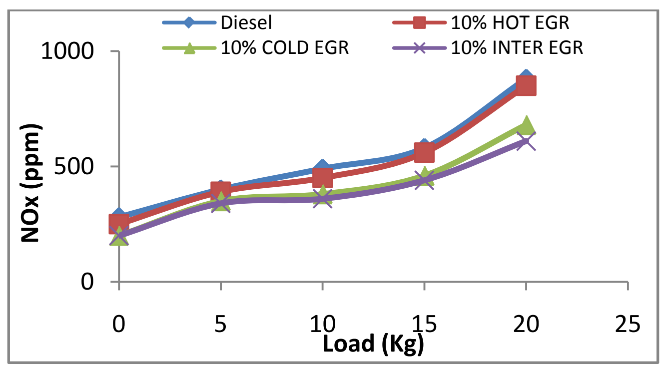

Figure 5 : LOAD Vs NO_x for 15% EGR

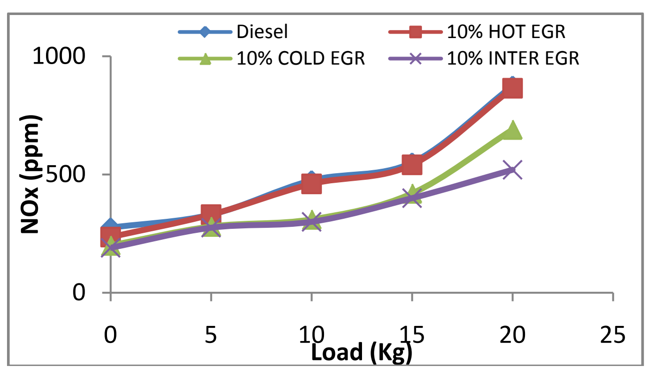

Figure 6 : LOAD Vs NO_x for 20% EGR

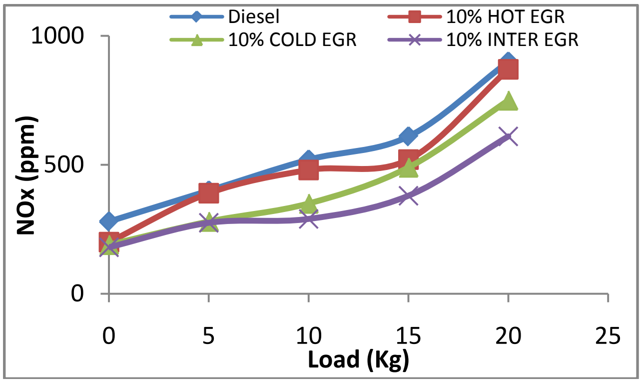

Figure 7 : LOAD Vs NO_x for 25% EGR

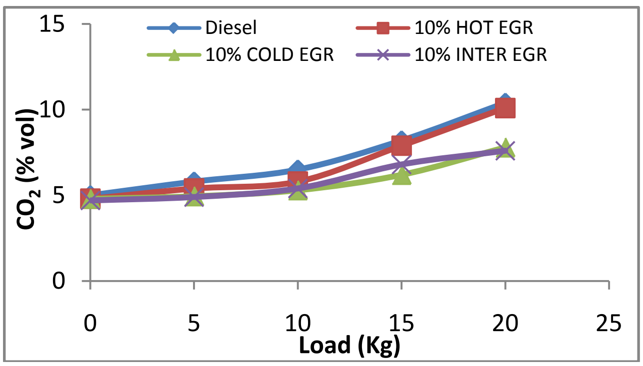

Figure 8 : LOAD Vs CO_2 for 10% EGR

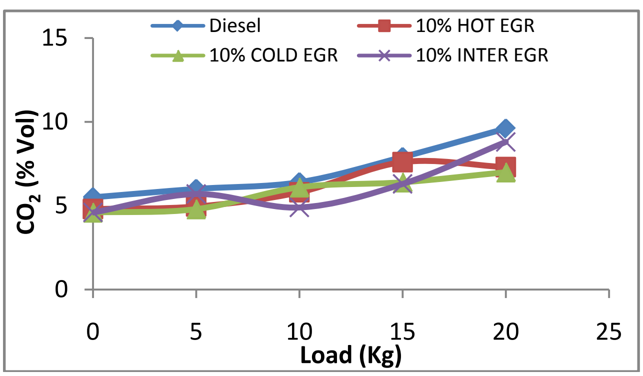

Figure 9 : LOAD Vs CO_2 for 15% EGR

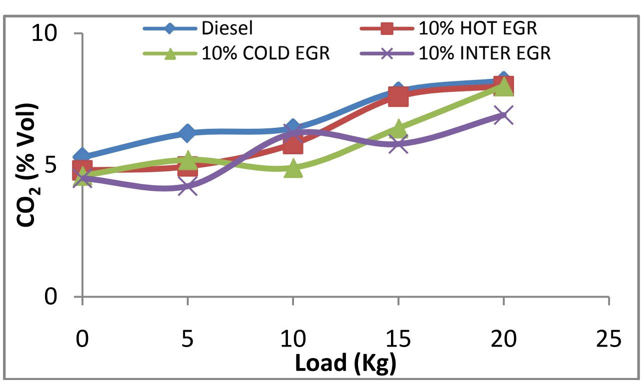

Figure 10 : LOAD Vs CO_2 for 20% EGR

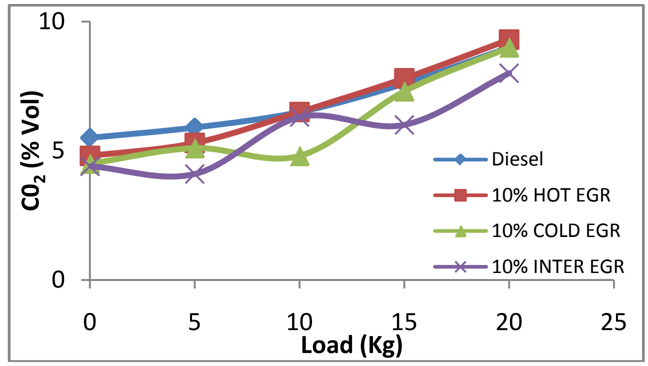

Figure 11 : LOAD Vs CO_2 for 25% EGR

IV. Conclusion

From the experimental results obtained, we infer that exhaust gas recirculation resulted in NOx reduction with slight decrease in the efficiency. NOx is increasing at partial loads and decreasing at higher loads. The trade-off between NO_x formation and other gases are diverging with load conditions. Also the results shows that cold EGR is much effective than hot EGR. From gas behavior 15-25% of cold EGR reduces the formation of NOx very well. Future researches can be carried out by experiments on EGR with other techniques like alternative fuels and variable geometry turbocharger for compromising the decrease in performance.

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