EFFECT OF EXHAUST GAS RECIRCULATION (EGR) ON THE PERFORMANCE AND EMISSION CHARACTERISTICS OF DIESEL ENGINE

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ABSTRACT

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.

So the consumption of diesel and petroleum has been up surged. The diesel engine provides a high efficiency and hence it can help to reduce CO_2 emissions, which are believed to be the main cause of global warming. Diesel exhaust also contains toxic gases, mainly nitrogen oxides (NO_X) and soot particles. These emissions are therefore limited by the authorities in most countries.

A way to reduce the nitrogen oxide emissions of a diesel engine is the use of exhaust gas recirculation, EGR. Here, a part of the exhaust gases is rerouted into the combustion chamber. This leads to a lower peak combustion temperature which in turn reduces the formation of NOX. In modern turbocharged engines it can be problematic to provide the amount of EGR that is needed to reach the emission limits. Other concerns can be the transient response of both the EGR-system and the engine.

The objective of this work is to study the effect of EGR on the performance and emission characteristics of the CI engine. A single cylinder, water cooled, variable speed direct injection diesel engine was used for this experiment. The content of HC, NOx, CO and smoke in the exhaust gas were measured to estimate the emissions. Application of EGR resulted in the increase in the performance of the engine and reductions in NOx emissions without any significant upsurge in smoke emissions. The graphs were plotted comparing the emissions from diesel with 0%, 5%, 10%, 15% EGR.

1. INTRODUCTION

All internal combustion engines generate power by creating explosions using fuel and air. These explosions occur inside the engine cylinder, the next explosion forcing the exhaust gases out of the cylinder. The need to control the emissions from automobiles gave rise to the computerization of the automobile [1]. Hydrocarbons, carbon monoxide and oxides of nitrogen are created during the combustion process and are emitted into the atmosphere from the tail pipe.

The search for alternative fuels which are eco friendly and can be used as a substitute to conventional HC based fuels is in demand due to concerns about depletion of fossil fuel reserves and also growing awareness against global warming.

Reducing NOx emission in a diesel engine is a major issue for its environmentally harmful influences. To cope with the problem, the current diesel engine is equipped with EGR. Actually, it is known that EGR can help to reduce NOx emission by limiting oxygen supplied into intake manifold, lowering the combustion temperature. However, it also reduces engine performance. Thus air flow control of a diesel engine is important to find an optimal trade-off point between engine performance and emission quantity. NOx emission can be adjusted by regulating burnt gas fraction which goes into intake manifold. However, burnt gas fraction is not easily measured or estimated because of its physical definition. Therefore, modified target like pressure and compressor flow was used to control desired intake burnt gas fraction indirectly [2]. Although modified target control is not required for an accurate air fraction sensor, there is a limitation that discrepancy between real burnt gas fraction and desired burnt gas fraction exists as a result of indirect control method.

1.1 Exhaust Gas Recirculation

Exhaust gas recirculation is an efficient method to reduce NOx emissions from the engine. The EGR system is designed to reduce the amount of oxides of nitrogen (NO_X) created by the engine during operating periods that usually results in high combustion temperatures, NOx is formed in high concentrations whenever combustion temperature exceed about 25000 F. In this recirculation system a portion of an engine's exhaust gases are recirculated back into the engine cylinders. In diesel engines exhaust gas replaces some of the excess oxygen in the combustion chamber. The EGR system reduces NOx production by recirculation small amount of exhaust gases into the intake manifold where it mixes with the incoming air. By diluting the air mixture under these conditions, peak combustion temperature and pressure are reduced, resulting in an overall reduction of NOx output. The aim of the present research study is to investigate the effect of EGR on emissions and performance parameters of an indirect injection diesel engine (IDI) fuelled with diesel.

Exhaust Gas Recirculation is an effective method for NOx control. The exhaust gases mainly consist of carbon dioxide, nitrogen etc. and the mixture has higher specific heat compared to atmospheric air. Re-circulated exhaust gas displaces fresh air entering the combustion chamber with carbon dioxide and water vapor present in engine exhaust. As a consequence of this air displacement, lower amount of oxygen in the intake mixture is available for combustion. Reduced oxygen available for combustion lowers the effective air–fuel ratio. This effective reduction in air–fuel ratio affects exhaust emissions substantially. In addition, mixing of exhaust gases with intake air increases specific heat of intake mixture, which results in the reduction of flame temperature. Thus combination of lower oxygen quantity in the intake air and reduced flame temperature reduces rate of NOx formation reactions. [3, 4] The EGR (%) is defined as the mass percent of the recirculated exhaust (MEGR) in the total intake mixture (Mi).

$$EGR\,(\%) = \frac{M_{EGR}}{M_i} \times 100$$

Desantes et al. used NDIR-based CO_2 concentration measurement at the intake ($[CO_2]_{int}$) and exhaust manifold ($[CO_2]_{exh}$) for the determination of EGR rate [5].

$$EGR = \frac{CO_{2\,int} - CO_{2\,atm}}{CO_{2\,exh} - CO_{2\,atm}}$$

Jaffar Hussain et al [6] have been carried out an experiment to investigate the effect of EGR on performance and emissions in a three cylinders, air cooled and constant speed direct injection diesel engine. They mainly focus on different EGR rate. They were measured the emission of hydrocarbons (HC), NOx, carbon monoxide (CO), exhaust gas temperature, and smoke opacity and also calculated the performance parameter such as thermal efficiency and brake specific fuel consumption (BSFC). They concluded that thermal efficiency is slightly decreased and BSFC is increased with EGR compared to without EGR. Exhaust gas temperature is decreased with EGR, but NOx emission decreases significantly. They observed that 15% EGR rate is found to be effective to reduce NOx emission substantially without deteriorating engine performance in terms of thermal efficiency, BSFC, and emissions. EGR can be applied to diesel engine without sacrificing its efficiency and fuel economy and NOx reduction can thus be achieved. The increase in CO, HC, and PM emissions can be reduced by using exhaust after-treatment techniques, such as diesel oxidation catalysts (DOCs) and soot traps [7] and its impact on reducing NOx emissions from bio diesel fuel combustion.

2. METHODOLOGY

2.1. Experimental set-up

Experimental study is carried out on a Kirloskar make, 1C, 3.5 kW, variable speed diesel engine. Performance tests are conducted on an engine at fixed compression ratio of CR18 and varying load (25%, 50%, 75% and 100%) using diesel and varying EGR (0%, 5%, 10%, 15%) to determine BSFC , BThE and ExGT. Engine emissions such as CO, HC and NOx were measured by using gas analyzer. Figure 1 and 2 shows the schematic diagram of the experimental setup and pictorial view respectively.

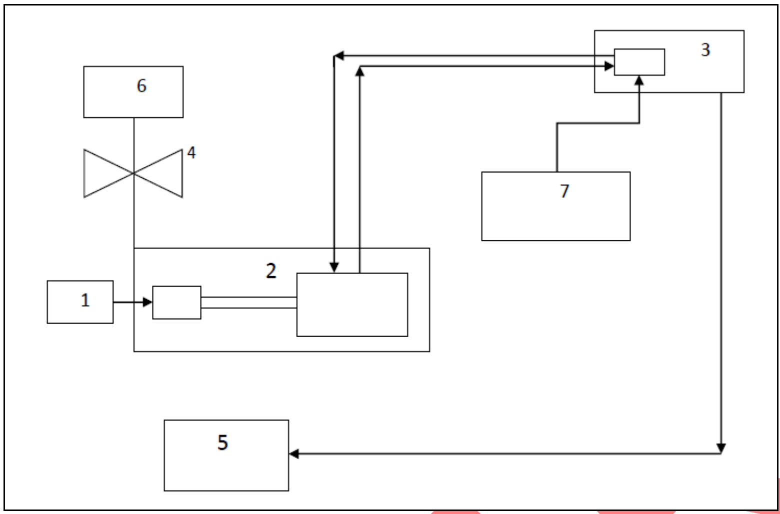

Figure 1 Line Diagram of EGR Setup

1 Electrical loading, 2 Single cylinder 4-stroke diesel engine & Alternator, 3 Exhaust gas Recirculation System, 4 Control valve, 5 Gas Analyzer& Smoke meter, 6 Fuel Tank, 7 Air drum

Figure 2 Pictorial View of EGR Setup

3. RESULTS AND DISCUSSION

3.1. Engine performance

After the engine reached the stabilized working condition for each test, fuel consumption, torque applied and exhaust temperature were measured from which BSFC, BThE were computed. The variations of these parameters with respect to load are presented in figure 1 to 3 at different EGR.

3.1.1 Brake Specific Fuel Consumption

It can be seen from Figure 3 that the BSFC lines for different EGR rates came closer to each other as load was increased from 25 to 100%, indicating a comparable performance of the engine with EGR at higher load. The variation in BSFC at different EGR rates was less at full load conditions than at part load; possibly due to increased temperatures and consequently increased efficiencies of the engine.

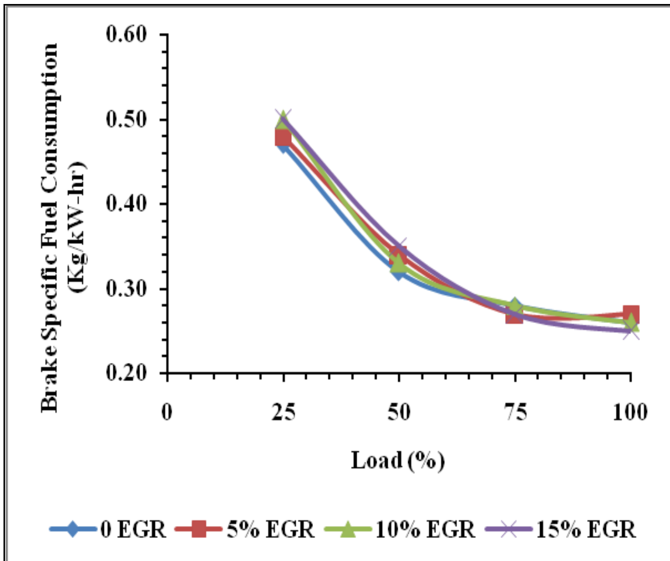

Figure 3 Variation of BSFC with Engine Load

3.1.2 Brake Thermal Efficiency

Based on the above results it can be concluded that the performance of the engine with EGR is comparable to that with no EGR engine, in terms of BThE. The brake thermal efficiency of the engine was low at part loads as compared to the engine running on full load. Thermal efficiency is found to be slightly up surged with EGR at all level of engine loads. At the maximum load for 15% EGR, thermal efficiency is lowered.

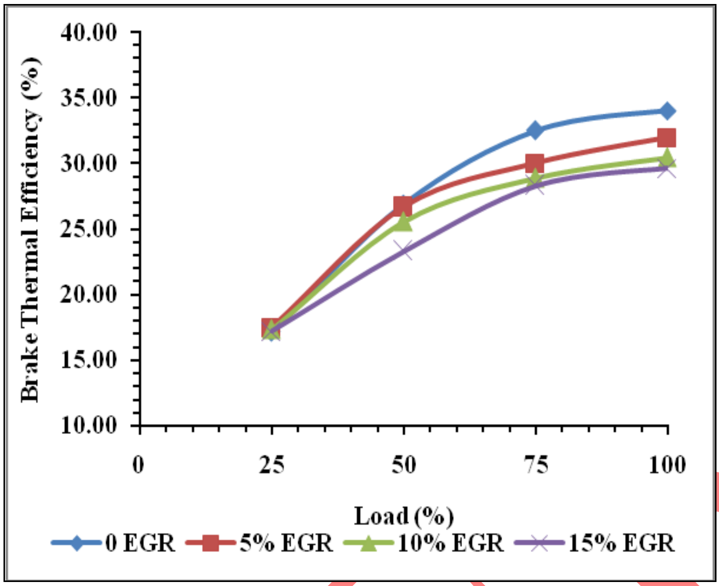

Figure 4 Variation of BThE with Engine Load

3.2. Engine Emission Characteristics

3.2.1 Carbon Monoxide

Figure 5 shows variation of the CO with load for the different EGR rates for the CI engine.

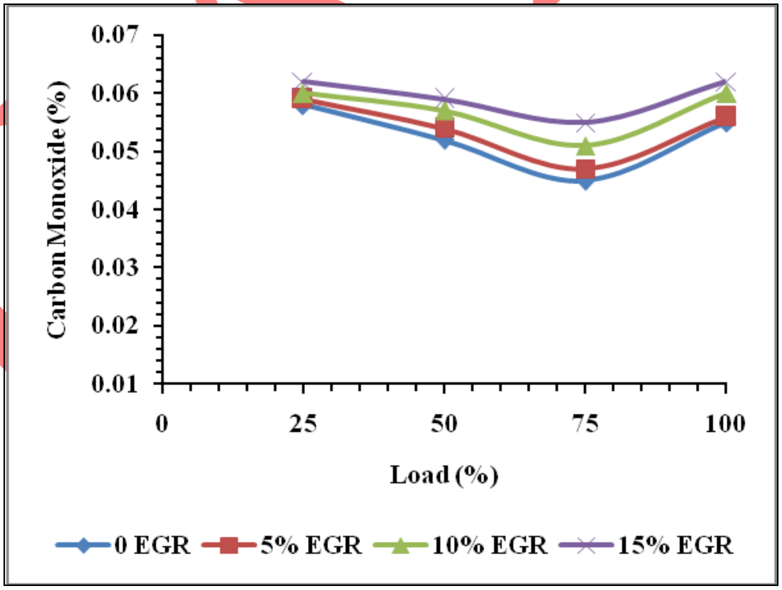

Figure 5 Variation of CO with Engine Load

The presence of CO in the exhaust gas of an engine is a representation of the chemical energy of the fuel which is not fully utilized. Generally, the CO emission is affected by the fuel type, combustion chamber design and atomization rate, engine load and engine speed. It is observed from the above figures that the CO emission decreases with the increase in load upto certain load and increases later.

3.2.2 Hydrocarbons (HC)

Figure 6 shows variation of the HC with load for the different EGR rates for the CI engine. There is reduction in HC emission in case of 15% EGR at the maximum load as shown in figure.

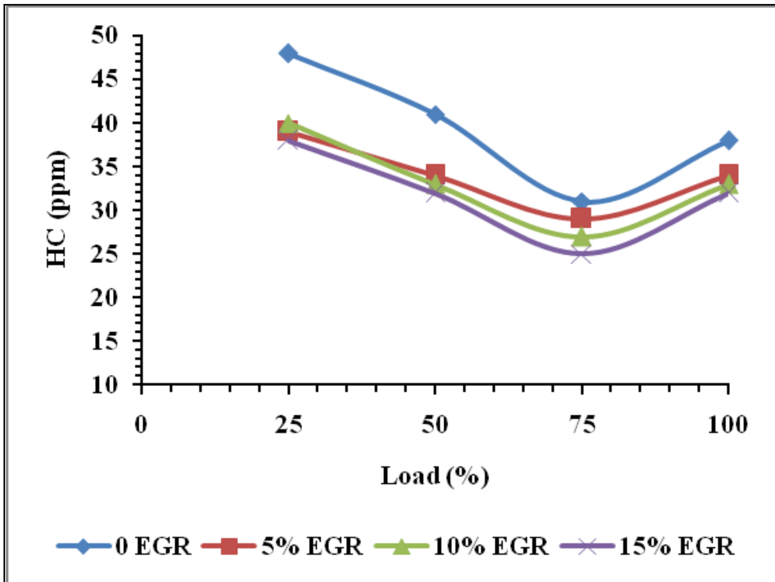

Figure 6 Variation of HC with Engine Load

3.2.3 Oxides of Nitrogen

Figure 7 shows variation of NOx emissions with load from diesel engine for different EGR rates. When EGR is applied, NOx emission is decreased with increase in the EGR rates. The reason behind this is, reduced oxygen concentration because of dilution of intake charge and decreased flame temperature. The EGR rate cannot be raised beyond the limit as thermal efficiency will decrease in a high rate.

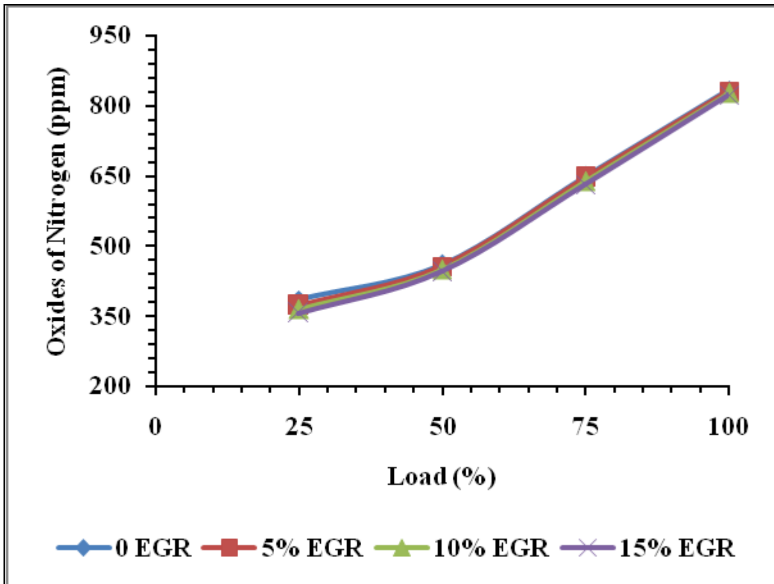

Figure 7 Variation of NOx with Engine Load

4. CONCLUSIONS

Based on the results of this study, it can be concluded that the BSFC, BThE of the engine are function of the load and EGR rates. 15% EGR is found to be optimum, which improves the thermal efficiency as well as reduces the exhaust emissions and BSFC. The higher NOx emission can be effectively controlled by engaging EGR. Therefore, it was concluded that engine operation with EGR results in NOx reductions without compromising engine performance.

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