Combine Effect of Boost Pressure and Exhaust Gas Recirculation (EGR) On Performance and Emission of Constant Speed Compression Ignition Engine: A Review

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Abstract--- An experimental study has been carried out for combined effect of Exhaust Gas Recirculation (EGR) system and boost pressure on performance and emission of constant speed compression ignition engine. As we know that the diesel engine (CI engine) are known for their high NOx formation and Exhaust Gas Recirculation (EGR) is being used widely to reduce and control the oxides of nitrogen (NOx) emission from diesel engines. EGR controls the NOx because it lowers oxygen concentration and flame temperature of the working fluid in the combustion chamber. However, the use of EGR leads to a trade-off in terms of soot emissions moreover it exhausted more unburned hydrocarbons (20–30%) compared to conventional engines and it also affect the efficiency and bsfc of engine performance. Present experimental study were carried out in a single cylinder, water cooled and constant speed direct injection four stroke diesel engine to experimentally evaluate the performance and emissions for three different EGR rates and three different values of inlet air pressure of the engine. This experiment is conducted to see the potential of EGR combine with inlet air pressure. Three different rates: 5%, 10% and 15% of this exhaust gas will recirculate in engine and inlet air pressure ranges from 100 kPa, 120 kPa and 140 kPa is selected to check the effect EGR on different loading conditions. Thus increasing boost pressure of inlet air along with EGR system give improvement in bsfc and brake thermal efficiency also reduce more NOx emission. Experiment was conducted in a four stroke direct injection water cooled constant speed diesel engine with increasing boot pressure attachment and EGR system, which is typically used in agricultural farm machinery. EGR was applied to the experimental engine separately and also with boost pressure to observe their effects on engine performance and emission. In this study, compressor was used to increase the boost pressure of inlet air. The experiments were carried out to experimentally evaluate the performance and emissions for different EGR rates 10%, 15% and 20% and boost pressure 120 kPa, 140 kPa and 160 kPa of the engine. Emissions of NOx, carbon monoxide (CO), hydrocarbons (HC), carbon dioxide (CO_2) and exhaust gas temperature of the exhaust gas were measured. Performance parameters such as Brake thermal efficiency, brake specific fuel consumption (BSFC) were calculated. It was found that combined effect of boost pressure attachment and EGR system provided better result on engine performance than individual EGR effect. Reductions in NOx and exhaust gas temperature were observed but emissions of HC, CO and CO_2 were found to have increased with usage of EGR and boost pressure. Thus the modified engine provides reduction in NOx and better fuel economy without reducing useful characteristics (brake power, bsfc, brake thermal efficiency etc) of the engine.

Keywords: Diesel engine, NOx emissions, Exhaust Gas Recirculation

I. INTRODUCTION

This chapter starts by describing the problems related environmental pollution. The aims and objectives of the research are outlined and novel ideas discovered during the research are listed. In this chapter, there is a short description about thesis. It is also presents the road map for problem definition to experimental setup. The Energy Consumption has been increased due to rapid growth in Industrialization and Individual mobility in today's World. Such causes a growth in transportation sector owing increased fuel consumption and environmental problems. The engineers are continuously developing the power units for the fulfilment of the industrial growth and to provide transportations. The diesel engines are widely used and well established machines, in the development of power units. Better fuel economy and higher power with lower maintenance cost has increased the popularity of diesel engine vehicles. Now a day's diesel engine because of its unique combination of energy efficiency, power, reliability, and durability, diesel technology plays a vital role in important sectors of the country economy. More than 90 percent of commercial trucks are powered by diesel engines, as are two-thirds of all farm and construction equipment, and 100 percent of all freight locomotives, river barges and other marine work vessels are also used diesel engine. Diesel engines also power electric generators used for distributed generation or as emergency back-up power such as those used by hospitals, different diesel power plants are universally adapted to supplement hydroelectric or thermal stations and as central stations for small capacity in the range of 2 to 50 MW capacity. The diesel engines are more favorable compare to others because of their inherently high thermal efficiencies, resulting from their high compression ratio and fuel lean operations. The high temperature is produced due to the higher compression ratio required for the achievement of auto-ignition point for the combustion of diesel. Higher compression ratio leads to higher expansion ratio which tends to discharge less thermal energy in the exhaust system. In most of the global car markets, record diesel car sales have been observed in recent years [1]. The most difficult problems that an engineer and manufacturers faces during diesel engine development are the control and reduction in pollutant emissions. The exhorting anticipation of additional improvements in diesel fuel and diesel vehicle sales in future have forced diesel engine manufacturers to upgrade the technology in terms of power, fuel economy and emissions. Diesel emissions are categorized as carcinogenic.

A. Mechanism of NOx formation

A major hurdle in understanding the mechanism of formation and controlling its emission is that combustion is highly heterogeneous and transient in diesel engines.
While NO and NO2 are lumped together as NOx, there are some distinctive differences between these two pollutants. NO is a colorless and odorless gas, while NO2 is a reddish brown gas with pungent odour. Both gases are considered toxic; butNO2 has a level of toxicity 5 times greater than that of NO. Although NO2 is largely formed from oxidation of NO, attention has been given on how NO can be controlled before and after combustion (Levendiset al 1994). NO is formed during the post flame combustion process in a high temperature region. The most widely accepted mechanism was suggested by Zeldovich (Heywood 1988). The Principal source of NO formation is the oxidation of the nitrogen present in atmospheric air. The nitric oxide formation chain reactions are initiated by atomic oxygen, which forms from the dissociation of oxygen molecules at the high temperatures reached during the combustion process.
The principal reactions governing the formation of NO from molecular nitrogen are,

$$N2 + O \rightarrow NO + N$$
$$N + O_2 \rightarrow NO + O$$
$$N + OH \rightarrow NO + H$$

In diesels, NO2 can be 10 to 30% of total exhaust emissions of oxides of nitrogen. The local atomic oxygen concentration depends on molecular oxygen concentration as well as local temperatures. Formation of NOx is almost absent at temperatures below 2000K.Hence any technique, that can keep the instantaneous local temperature in the combustion chamber below 2000 K, will be able to reduce NOx formation.

II. NOX CONTROLING METHODS

A. Exhaust Gas Recirculation (EGR)

The main principle employed in EGR is re-circulation of a portion of an engine's exhaust gas back to the engine cylinders. The re-circulated exhaust gas decreases the local temperature in the combustion chamber. It is mostly effective in particular time/space zones during which the NOx emission is produced, specifically during the fuel injection and after the end of the injections [1]. In the EGR system, the heat of combustion from the fuel is used to heat the exhaust gas. The exhaust gas is essentially inert and therefore does not react in the combustion chamber and only absorbs heat [2]. Even though, the EGR has a potential of reducing NOx up to 50%, it has an inherent drawback of increasing the PM emissions [3,4,5]. In addition, the heat absorption by exhaust inert gas in the cylinder chamber results in small amount of power loss from the engine as well

B. Concept of Exhaust Gas Recirculation (EGR)

Exhaust gas recycle is done by ducting some of the exhaust flow back into the intake system usually immediately after the throttle. EGR combines with exhaust residual left in the cylinder from the previous cycle to effectively reduce the maximum combustion temperature.

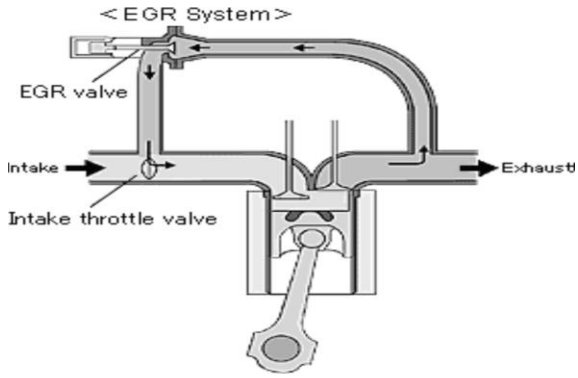

Fig. 1

The exhaust gas acts as an inert gas in the combustion chamber, it does not participate in the combustion reaction. This leads to a reduction of the combustion temperature by different effects. The fuel molecules need more time to find an oxygen molecule to react with, as there are inert molecules around. This slows down the combustion speed and thus reduces the peak combustion temperature, as the same amount of energy is released over a longer period of time. This causes a correspondingly lower heat release and peak cylinder temperature, and reduces the formation of NOx. The presence of an inert gas in the cylinder further limits the peak temperature (more than throttling alone in a spark ignition engine). The amount of flow can be as high as 30% of the total intake. The flow rate of EGR is controlled by the Engine Management System. A valve is usually used to control the flow of gas, and the valve may be closed completely if required. Exhaust Gas may also passes through cooled EGR, which are air/water type. This reduces the temperature of exhaust gas and again cylinder temperature. This has two benefits- the reduction of charge temperature results in lower peak temperature, and the greater density of cooled EGR gas allows a higher proportion of EGR to be used. On a diesel engine the recirculated fraction may be as high as 50% under some operating conditions. The configuration of Most of the EGR systems has following main hardware components:

- One or more EGR control valves,
- One or more EGR coolers and
- Piping, flanges and gaskets.

Other specialized components are possible in certain types of systems, such as venturi mixer devices or EGR pumps.

III. PERFORMANCE ANALYSIS

Figure (2) represents brake specific fuel consumption at atmospheric inlet air pressure for different EGR rate. With increasing rate of EGR, the BSFC is increased because the oxygen available in air for combustion gets reduced and thus, fuel air ratio is changed and this increases the BSFC. Also with increasing EGR rate, exhaust gas has higher amount of CO_2, which reduces maximum temperature in combustion chamber along with oxygen availability therefore burning of fuel is not significant. Figure (B) shows the trend of decrement in thermal efficiency with increasing EGR rate.

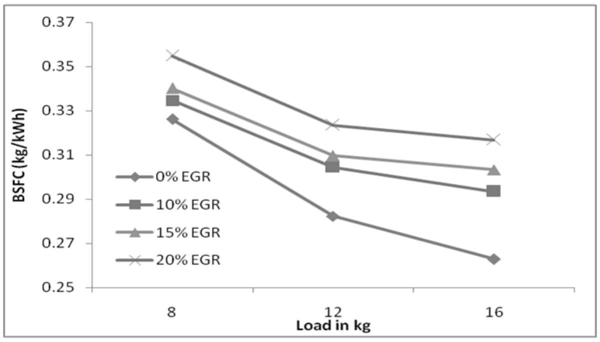

Fig. 2

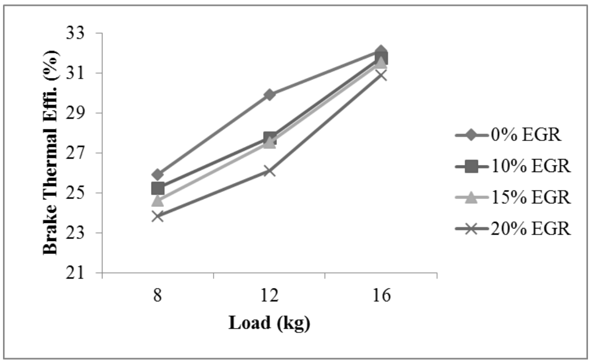

Fig. 3

A. Emission Analysis

The emission of NOx for different EGR rates and different loads at atmospheric inlet air pressure. This figure shows the main benefit of EGR system in reducing NOx emission from the diesel engine. The reduction in NOx emissions is occurred using EGR system in diesel engines because of reduce the oxygen concentration and decreased flame temperatures in the combustible mixture.

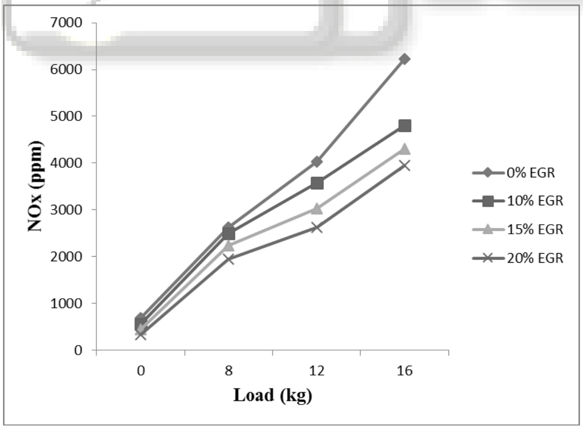

Fig. 4

The degree of reduction in NOx at higher load is higher. This is basically the result of three major effects on the combustion process the thermal effect, dilution effect and chemical effect. Due to CO_2 and H_2O the specific heat of exhaust gas is high, compare to normal air which has a major content of O_2 and N_2. This increases the heat capacity of the inlet charge, which result in a lower flame temperature during the combustion process. While in dilution effect the combustion of O_2 inside the cylinder is decreased which decelerate the mixing process between O_2 and fuel. In chemical process, the recirculated H_2O and CO_2 dissociate during this endothermic process and modify the combustion process and NOx formation. Such endothermic process also decreases the flame temperature.

At the part load, O_2 is available insufficient quantity but at high loads, O_2 reduces drastically, therefore NOx is reduced more at higher loads compared to part loads. EGR has a positive effect on the emission of NOx but it has negative effect on HC, CO and CO_2 emission.

The effect of different rate of EGR on CO, HC and CO_2 emission at atmospheric inlet air pressure for different load condition respectively

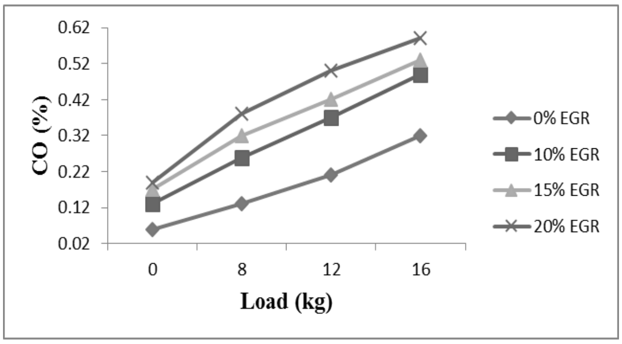

Fig. 6

It was observed from the experiment that emission of CO, HC and CO2 increased with increasing rate of EGR. The possible reason may be with increasing rate of EGR causes lower in excess oxygen concentration and decreased the combustion temperature this results in rich air-fuel mixtures at different locations inside the combustion chamber and decreased the wall temperature. This heterogeneous mixture does not combust completely and results in higher CO, HC and CO_2 emissions. At part loads, lean mixtures are harder to ignite because of heterogeneous mixture and produce higher amount of HC, CO and CO_2

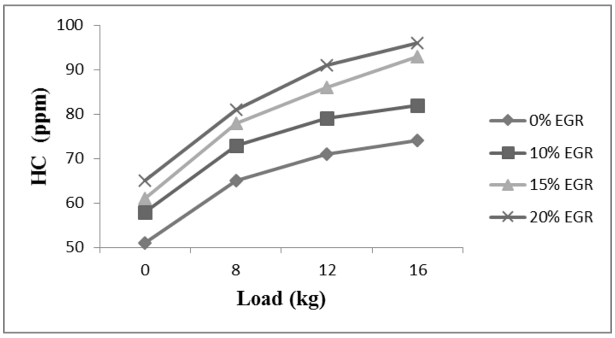

Fig. 5

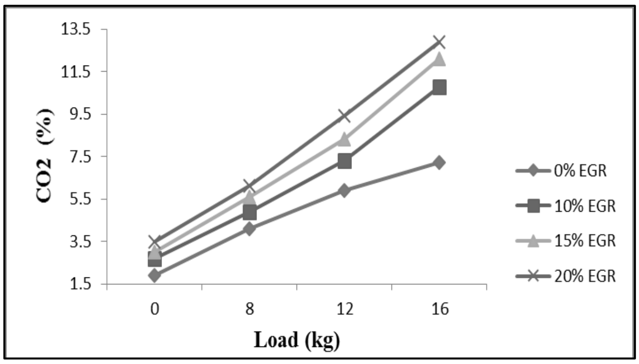

Fig. 6

Exhaust gas recirculation system has a positive effect on reduction of NOx formation but has a negative effect, as it causes decreased in thermal efficiency and increased in bsfc. It also increases the emission of CO, HC and CO_2. So, from above results the negative and positive effect of EGR is illustrated

In another practical work the experiments was conducted for increasing boost pressure with EGR system and observe the various effect of combining EGR system and increasing boost pressure of inlet air on the engine performance and emissions.

IV. CONCLUSION

- The emission of NOx is reduced significantly by combined effect of increasing boost pressure of inlet air and increasing EGR rate than individual increasing rate of EGR.
- It was also observed from the experiment that combined effect of increasing boost pressure attachment and EGR system provided better BSFC and brake thermal efficiency of engine. BSFC decreases and brake thermal efficiency increases by increasing boost pressure of inlet air with EGR system than individual EGR system.
- The increase in emission of CO, HC, and CO_2 can be reduced by using exhaust after-treatment techniques, such as diesel oxidation catalysts (DOCs) and soot traps.

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