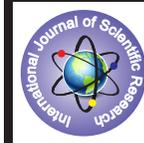


Review on Combine Effect of Exhaust Gas Recirculation (Egr) and Inlet Air Pressure on Performance And Emission of Diesel Engine



Engineering

KEYWORDS : Exhaust gas recirculation, Diesel engine, Inlet air pressure, Emission

Patel Vibha R.

P.G. Student, Mechanical Department, Subject of Thermal Engineering, Jodhpur National University, Jodhpur

Prof. Hardik B. Ramani

Assistant Professor, Mechanical Department, OM. College of Engineering, Junagadh

ABSTRACT

Concern of environmental pollution and energy crisis all over the world have caused the research attention on reduction of diesel engine exhaust emissions and saving of energy simultaneously. Better fuel economy and higher power with lower maintenance cost has increased the popularity of diesel engine vehicles. Diesel engines are used for bulk movement of goods, powering stationary/mobile equipment, and to generate electricity more economically than any other device in this size range. As we know that the diesel engine are known for their high NO_x formation and Exhaust Gas Recirculation (EGR) is being used widely to reduce and control the oxides of nitrogen (NO_x) emission from diesel engines. EGR controls the NO_x 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 volumetric efficiency and BSFC of engine performance. The increased in inlet air pressure results in better scavenging and reduced exhaust temperature in the engine, better mechanical efficiency and improved volumetric efficiency. Therefore, by using EGR with pressurized inlet air have different effect on both engine emission such as CO, UHC and NO_x and on the engine performance such as BSFC, torque, thermal and volumetric efficiency.

INTRODUCTION

Diesel engines are among the most effective engines in the world. Known as strong, economical and robust, they are also recognized for their traditional smoke and high level of nitrous oxides, NO_x emissions. The diesel cycle was developed by the

German engineer, Rudolf Christian Karl Diesel, considered the first engineer who applied the thermodynamic theory to develop combustion engines. Continuous research and development turned the diesel engine highly efficient. Its application includes propulsion units for ships, train and load vehicles such as buses and trucks besides; it is used as power source in auxiliary machinery, such as emergency diesel generators, pumps and compressors. At the same time, a drawback of diesel engines is that they are harmful to human health and the environment due to pollutant emissions. A

Comparison between Otto engines, largely applied to passenger cars and diesel engines, in general terms, shows a diesel engine characterized by low specific fuel consumption and low CO and UHCs (unburned hydrocarbons) emissions. On the other hand, NO_x emissions are huge in the diesel cycle [3]. Hence, in order to meet the environmental legislations, it is highly desirable to reduce the amount of NO_x in the exhaust gas.

In most of the global car markets, record diesel car sales have been observed in recent years [1]. 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 [2]. Therefore Diesel manufacturers and researchers have been investigating a variety of techniques in the hope of reducing diesel emissions and comply with exhaust emission legislation as far as reasonably practicable. For reducing vehicular emissions, several baseline technologies are being used. These technologies can be classified into two different categories, according to their emission-control techniques. The first prevents emission.

formation in the engine cylinder through the use of improved combustion technologies, such as high-pressure injection, low compression ratio bowls, and exhaust gas recirculation (EGR). The second uses purifying devices, such as diesel particulate filters (DPFs), selective catalytic reduction (SCR), and lean NO_x traps (LNTs).

Instead of using after-treatment systems to comply with exhaust emission legislation, it is also possible to avoid the forma-

tion of emissions during the combustion. The raw emissions are reduced and thus no after-treatment is needed. It is common practice nowadays, to use EGR to reduce the formation of NO_x emissions. Exhaust Gas Recirculation (EGR) System

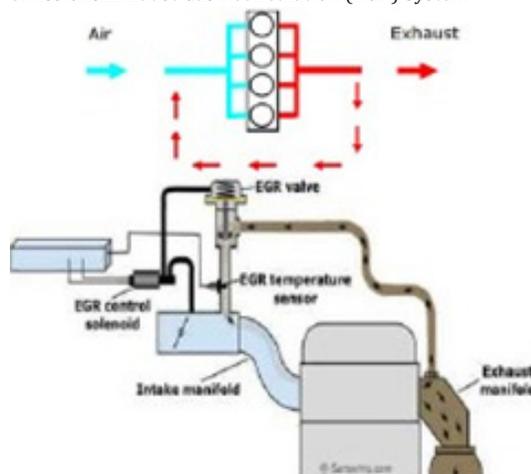


Figure- 1: Exhaust Gas Recirculation

Exhaust Gas Recirculation (EGR) is an effective pretreatment technique, which is being used widely to reduce and control the oxides of nitrogen (NO_x) emission from diesel engines. The exhaust gas mainly consist of carbon dioxide, nitrogen etc. and the mixture has higher specific heat compared to

atmospheric air. EGR controls the NO_x because it lowers oxygen concentration and flame temperature of the working fluid in the combustion chamber. 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 NO_x formation reactions [4, 5].

The EGR (%) is defined as the mass percent of the recirculated exhaust (MEGR) in the total intake mixture (Mi).

Desantes et al. used NDIR-based CO₂ concentration Based measurement at the intake ([CO₂]_{int}) and exhaust manifold ([CO₂]_{jexh}) for the determination of EGR rate [6].

The engines using EGR emit lower quantity of exhaust gases compared to non-EGR engines because EGR part of the exhaust gas is re-circulated [7].if the concentration of toxic substances in the exhaust gas remains unchanged, the total quantity of emission of toxic substances reduce for the same volumetric concentration. An investigation was conducted by Ladommatos et al. (1998) on a high speed- direct injection diesel engine and was concerned with the effects of exhaust gas recirculation (EGR) on diesel engine combustion and emissions. In particular, the effects on combustion and emissions of carbon dioxide and water vapor (H₂O), principal constituents of EGR, were analyzed and quantified experimentally. It was found that when CO₂ or H₂O displaced O₂ in the inlet charge, both the chemical and thermal effects on exhaust emissions were small. However, the dilution effect was substantial, and resulted in very large reductions in exhaust NO_x at the expense of higher PM emissions.

Schubiger et al. (2001) focused on the effects of EGR used in combination with very high injection pressure. The NO_x emissions decreased almost linearly with the EGR; extremely low NO_x emissions levels (less than 1 to 2 g/kWh) can be achieved at EGR rates up to 40%. A strong increase in the PM emissions was measured with high rates of EGR, but the effect can be significantly counteracted in a certain range by using very high injection pressures up to 160 MPa.

Jacobs et al. (2003) studied the complex interactions resulting from the application and control of EGR on a production heavy duty diesel engine system, and its effectiveness in reducing NO_x emissions. It was shown that EGR provides an effective means for reducing flame temperatures and NO_x emissions, particularly under low air to fuel (A/F) ratio conditions. However, engine thermal efficiency tends to decrease with EGR as a result of decreasing indicated work and increasing pumping work.

Wenzel et al. (2006) studied the effect of EGR and its impact on reducing NO_x emissions from bio diesel fuel combustion. The application of EGR was found to be an effective method of reducing NO_x emissions from biodiesel fuel.

An experimental study was conducted by Maiboom et al. (2008) on a 2.0 l HSDI automotive diesel engine under low load and part load conditions in order to distinguish and quantify some effects of EGR on combustion and NO_x/PM emissions. At low load conditions, use of high EGR rates at constant boost pressure is a way to drastically reduce NO_x and PM emissions but with an increase BSFC and in other emissions (CO and hydrocarbon), whereas EGR at constant air/fuel ratio may drastically reduce NO_x emissions without important penalty on BSFC and soot emissions but is limited by the turbo charging system.

Deepak Agarwal et al (2011) conducted experiment using EGR on two cylinder constant speed diesel engine generator set and found that thermal efficiency is slightly increased with EGR at lower engine loads as shown in fig 2.

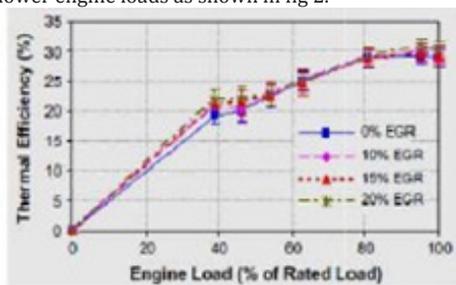


Figure-2: Thermal efficiency for different EGR rates.

The possible reason may be re-burning of hydrocarbons that enter the combustion chamber with the re-circulated exhaust gas. At part loads, exhaust circulated gas has less CO₂ and fairly high amount of O₂. Also, partly-cooled EGR acts like a pre-heater of the intake heater mixture. When this exhaust gas is re-circulated in the cylinder, the unburned HC in exhaust gas burns because of sufficient O₂ available in combustion chamber and reasonably high intake temperatures. At higher engine loads, the thermal efficiency remains unaffected by EGR. At higher loads, exhaust gas has higher amount of CO₂, which reduces maximum temperature in combustion chamber along with oxygen availability therefore re-burning of HC is not burning Significant.

Fig. 3 represents comparison of BSFC for all datasets using EGR with baseline data. BSFC is lower at lower loads for engine operated with EGR compared to without EGR. However, at higher engine loads, BSFC with EGR is almost similar to that of without EGR. At higher loads, amount of fuel supplied to the cylinder is increased at higher rate and oxygen available for combustion gets reduced. Thus, air fuel ratio is changed and this increases the BSFC.

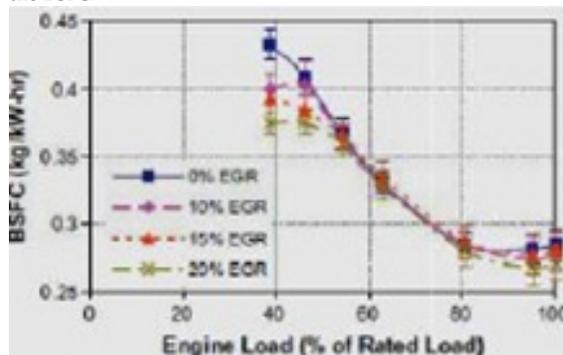


Figure- 3: Brake specific fuel consumption for different EGR rates.

Fig. 4 represents volumetric efficiency for different EGR rates. It can be seen that as the EGR rate is increased, volumetric efficiency decreases. The intake air mass flow reduces because of EGR implementation and this means the volumetric efficiency drops. Ghazikhani et al. also found that zikhani volumetric efficiency drops when EGR rate is increased [8].

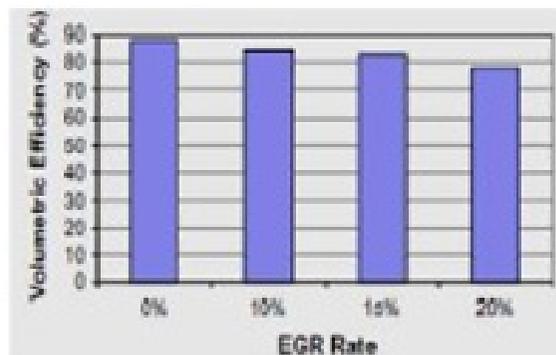


Figure- 4: Volumetric efficiency for different EGR rates.

Effect of EGR on unburned hydrocarbon (HC) and carbon monoxide (CO) are shown in Figs. 5 and 6, respectively. These graphs show that HC and CO emissions increase with increasing EGR. Lower excess oxygen concentration results in rich air-fuel mixtures at different locations inside the combustion chamber. This heterogeneous mixture does not

combust completely and results in higher hydrocarbons, carbon monoxide emissions. At part loads, lean mixtures are harder to ignite because of heterogeneous mixture and produce higher amount of HC and CO.

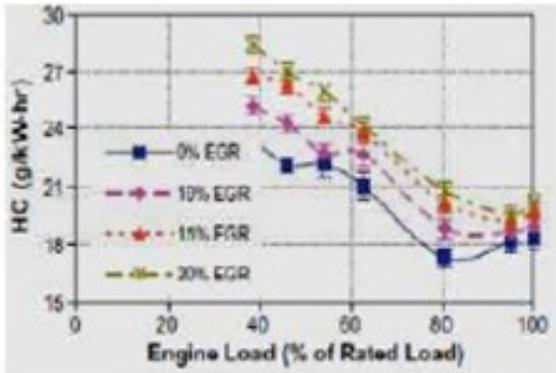


Figure- 5: hydrocarbons for different EGR rates:

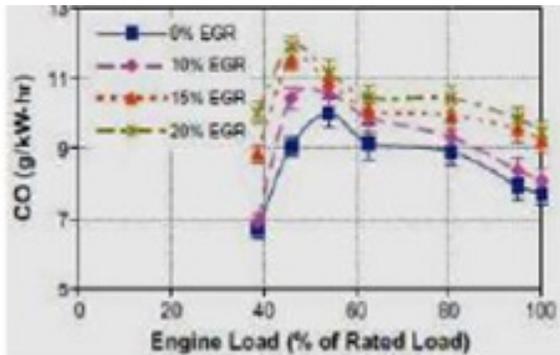


Figure- 6: Carbon monoxide for different EGR rates.:

Fig. 7 shows the main benefit of EGR in reducing NO_x emissions from diesel engine. The degree of reduction in NO_x at higher loads is higher. The reasons for reduction in NO_x emissions using EGR in diesel engines are reduced oxygen concentration and decreased flame temperatures in the combustible mixture. At the part load, O₂ is available in sufficient quantity but at high loads, O₂ reduces drastically, therefore NO_x is reduced more at higher loads compared to part loads.

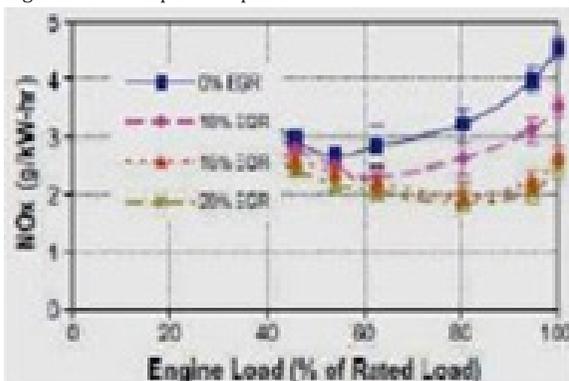


Figure- 7: NOx for different EGR Rates.

They found that thermal efficiency is slightly increased and BSFC is decreased at lower loads with EGR compared to without EGR. But at higher loads, thermal efficiency and BSFC are almost similar with EGR than without EGR. Exhaust gas temperature is decreased with EGR. Hydrocarbons, carbon monoxide, and smoke opacity are increased with EGR, but NO_x emission decreases significantly.

It can be observed that 15% EGR rate is found to be effective to reduce NO_x emission substantially without deteriorating engine performance in terms of thermal efficiency, BSFC, and emissions. At lower loads, EGR reduces NO_x without deteriorating performance and emissions. At higher loads,

increased rate of EGR reduces NO_x to a great extent but deteriorates performance and emissions. Thus, it can be concluded that higher rate of EGR can be applied at lower loads. EGR can be applied to diesel engine without sacrificing its efficiency and fuel economy and NO_x 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.

Advantages of EGR

- Reduced NO_x.
- Improved engine life through reduced cylinder temperatures (particularly exhaust valve life).

Drawback of EGR

- Reduced volumetric efficiency [9].
- Unaffected thermal efficiency and BSFC at higher load [9].

These drawbacks can be reduced by using pressurized inlet air. The use of pressurized inlet air may have different effect on thermal efficiency, exhaust emission, brake power, in-cylinder pre-heat cylinder release rate and fuel consumption. The increased in inlet air pressure results in better scavenging and

reduced exhaust temperature in the engine, better mechanical efficiency and improved volumetric efficiency. The pressurized air increases the power output of the engine. It does not increase the fuel consumption, per brake kW hour. Therefore by using EGR with pressurized inlet air have different effect on both engine emission such as CO, UHC and NO_x and on the engine performance such as BSFC, torque, thermal and volumetric efficiency. These effects will find out after the experiment.

REFERENCE

- Annual diesel report. | <<http://www.ricardo.com/pages/dieseleport.asp>>. | Stewart KM. Health effects of diesel exhaust. Report | from American Lung Association of Pennsylvania; | 2001. | Walsh MP. Global diesel emission trends. Automotive | Eng Int 1998;114-8. | Ladommatos N, Balian R, Horrocks R, Cooper L. The | effect of exhaust gas recirculation on soot formation in | a high-speed direct-injection diesel engine.SAEinjection | 960841; 1996. | Abd-Alla GH. Using exhaust gas recirculation inAlla | internal combustion engines: a review. En Energy Convers | Manage 2002;43:1027-42. | Desantes JM, Galindo J, Guardiola C, Dolz V. Air mass | flow estimation in turbo charged diesel engine from inin- | cylinder pressure measurement. ExpTherm Fluid Sci | 2010;34:37-47. | Stumpp G, Banzhaf W. An exhaust gas recirculation | system for diesel engines.SAE 780222; 1978. | Ghazikhani M, Feyz ME, Joharchi A. Experimental | investigation of the exhaust gas recirculation effects on | irreversibility and brake specific fuel consumption of | indirect injection diesel engines. ApplThermEng 202010; | 30:1711-8. | Deepak Agarwal, Shrawan Kumar Singh, Avinash | Kumar Agarwal, Effect of Exhaust Gas Recirculation | (EGR) on performance, emissions, deposits and | durability of a constant speed compression ignition | engine. Applied Energy 88 (2011) 29002900-2907. |