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Research Article

Experimental investigation on Impact of Hot and Cold Exhaust Gas Recirculation on Diesel Engine with Cetane Improver

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Abstract

Today most of the transport vehicles in countries like India where cost effective is the predominant criteria utilize diesel engines rather than petrol engines. From past 5 years usage of diesel engines was rapid which can be addressed from the sales report of many automobile companies. The reason behind this could be cost of diesel fuel and efficiency of the diesel engine when compared to petrol engine. But when we look on the worse side of diesel engine, emissions from diesel engine are high especially NOx. So there is a need for a technique which could reduce the emissions without affecting the performance of engine. One such technique could be Exhaust gas recirculation and adding cetane improver to the fuel. To enhance the performance and reduce the other emissions other than NOx cetane improver di tert butyl peroxide (DTBP) was used. Present paper aims to find the impact of cold and hot EGR on emissions of diesel engine along with cetane improver.

Keywords: *Effective, Efficiency, Emissions,* NO_X

Introduction

It's been quite a while more researchers are turning their interest towards the implementation of new techniques in the space of automobile, more precisely reducing the emissions which became a big problem in recent past. One such technique would be Exhaust Gas Recirculation, which is not a new concept but there is great potential for exhaust gas technique if considerable research is done. Recently many countries have imposed emission legislation on NOx in diesel engines. Its known fact that diesel engines are more efficient in terms of economy but when we consider emissions from diesel engine, it emits more emissions especially NOx. So there is a great urge to reduce the NOx emissions in diesel engines.

Exhaust gas recirculation is a technique where some portion of exhaust gas is recirculated back with the fresh air into the cylinder. Exhaust consists of CO2, N2 and water vapour mainly. As exhaust gas doesn't burn anymore so they can be recirculated back into cylinder. When a part of this exhaust gas is re-circulated to the cylinder, it acts as a diluent to the combusting mixture. This also reduces the oxygen concentration in the combustion chamber. The specific heat of exhaust gas is much higher than that of fresh air. Hence EGR increases the specific heat of the intake charge, thus decreasing the temperature rise for the same heat release in the combustion chamber.

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Some researchers had focused on techniques which could reduce NOx from diesel engines. According to Ming Zheng et.al.EGR can be implemented to diesel engines with greater efficiency rather than other techniques which could reduce NOx from diesel engines. He briefly reviewed the paths and limits to reduce NOx emissions from diesel engines and highlighted the inevitable uses of EGR. The impact of EGR on diesel operations was analyzed and a variety of ways to implement EGR were outlined in his paper (Ming Zheng *et al*, 2004).

Experimental investigations by N. Ladommatos, et.al. analyzed and quantified the principle constituents of EGR, viz. carbon dioxide and water vapour. The effect of increased inlet temperature and thermal throttling of inlet charge, both arising from the use of the hot EGR, were also investigated.

Experiments conducted by K. Venkateswarulu using hot EGR along with cetane improver showed that there is significant effect on NOx emissions. Test results show that the brake thermal efficiency increases with the increase in the percentage of EGR which is accompanied by a reduction in brake specific fuel consumption and exhaust gas temperatures. There ws reduction in NOx by 33% (K. Venkateswarlu *et al*, 2012)

Mohamed Y.E. Selim studied the effects of EGR ratio, engine speeds, loads, temperature of recycled exhaust gases, intake charge pressure and engine compression ratio on combustion noise and thermal efficiency and observed that Exhaust gas recirculation at an EGR ratio of 5 % has a positive effect on increasing the thermal efficiency. The use of a low EGR ratio of 5% is also favorable for reduced combustion noise and reduced NOx emission. However, increasing the EGR reduces the thermal efficiency. The hot EGR increases the pressure rise rate at all loads and at all EGR ratios used as compared with cooled EGR (Mohamed Y.E. Selim *et al*, 2003).

Nidal H. Abu-Hamdeh carried out a study on spiral fin exhaust pipes , to determine the effect of cold EGR on the chemical composition of the exhaust gases and the reduction in the percentages of pollutant emissions in diesel engines. The gases examined in this study were oxides of nitrogen (NOx), carbon dioxide (CO2) and carbon monoxide (CO). In addition, O2 concentration in the exhaust was measured. The two designs adopted in this study were exhaust pipes with solid and hollow fins around them. The first type uses air flow around the fins to cool the exhaust gases. The second type consists of hollow fins around the exhaust pipe to allow cooling water to flow in the hollow passage. Different combinations and arrangements of the solid and hollow fins exhaust pipes were used. It was found that decreasing the temperature of the EGR resulted in reductions in the oxides of nitrogen (NOx) and carbon dioxide (CO2) but increased the carbon monoxide (CO) in the exhaust gases. In addition, the oxygen (O2) concentration in the exhaust was decreased. As a general trend, the percentages of reduction in the NOx gas concentrations were lower than the percentages of increase in the CO emissions as a result of cooling the EGR of a diesel engine by a heat exchanger. Using water as a cooling medium decreased the exhaust gas temperature and pollutants more, than did air as a cooling medium. In a separate series of tests it was observed that, increasing the cold EGR ratios decreased the exhaust NOx but increased the particulate matter concentrations in the exhaust gases (Nidal H *et al*, 2003).

E. Kazuya Ishiki, et.al. studied on the mechanism of wear induced by soot in the EGR gas. The piston ring of the test engine was chrome plated and the cylinder was made of boron steadite cast iron. Detailed observations of the ring sliding surfaces and that of the wear debris contained in lubricating oil were carried out. It was found that the wear of the top ring sliding surfaces identify abrasive wear without respect to the presence of EGR by steadite on the cylinder liner sliding surface. In addition, it was confirmed in a cutting test that soot mixed lubricating oil improved in performance as cutting oil. Based on these results, it was proposed that the ring wear is accelerated at EGR because abrasive wear increases due to a lot of soot mixed into lubricating oil improving the performance of lubricating oil as cutting oil (E. Kazuya Ishiki *et al*, 2000).

The addition of Di Methyl Carbonate (DMC) to diesel fuel increases efficiency marginally with reduction in NOx emissions while PM and soot emissions were reduced considerably [7, 8]. However low cetane number and high latent heat of vaporization while low viscosity and insufficient lubricity of Di Methyl Ether (DME) are the limiting factors of DMC as an additive (Sundar Raj *et al*, 2010).

Additives like Diethylene Glycol Dimethyl Ether and liquid cerium showed significant improvements in BSEC and exhaust emissions (Sathiyagnanam *et al*, 2010). Coated engines with Additives exhibited improved efficiency, in addition to the increase in cylinder pressure, reduction in NO_x and reduction in maximum heat release rate. Thermal Barrier Coated (TBC) DI diesel engine with fuel additives (di iso propyl ether) reduced the smoke density and NO_x emission of the engine exhaust (Manish Nandi.K *et al*, 2010). 1-4 dioxane, an ether derived from alcohol as an additive to the diesel fuel reduced smoke density with slight increase in NO_x and drop in fuel economy. Brake thermal efficiency is improved marginally and smoke reduced significantly with the blends when compared to neat diesel for TBC engines (Suppes,G.J *et al*, 2010).

Cetane improvers reduce the ignition delay(Kobori,S *et al*, 2000) which allows better cold starting, reduced NO_x emissions, and smoother engine operation .Ignition delay in engines plays an important role in combustion performance and reducing all regulated and unregulated emissions including NO_x emissions. Cetane improver with oxygenate such as glycol ether reduced particulate, HC, and CO emissions.Ethanol-diesel blends with EHN as additive increased BTE and reduced significantly the emissions like CO,THC, smoke, and particulates in CRDI diesel engine and also decrease cylinder pressure, ignition delay, the maximum rate of pressure rise, and the combustion noise. While Ethanol-diesel blends with cetane improver with advanced fuel injection angle shows a large decrease in exhaust smoke concentration and a small decrease in exhaust NOx concentration.

The present paper focuses on implementation of hot and cold EGR in a diesel engine. This is achieved by modifying an engine. Cetane improver di tert butly peroxide was added at a ratio of 0.5% to the diesel.

Experimental Setup

The experimental set-up is shown in Figure 1, which is computerized single cylinder four stroke, naturally aspirated direct injection and air cooled diesel engine. The specifications of the test engine are given in Table 1. Engine is loaded with an eddy current dynamometer. Engine is equipped with AVL GH12D miniature pressure transducer for measuring the pressure variation in the cylinder and AVL 615 Indimeter software which measures the heat release rate from the measured values of cylinder pressure at different crank angle. AVL five gas analyzer was used for measuring the CO, UHC, NO_x, CO_2 and AVL Smoke meter was used for measuring the smoke opacity. For circulation of exhaust gases into the intake manifold an EGR set up was provided which consists of a control valve and manometer. For obtaining cold EGR exhaust gas is been stored in a tank and cooled to a predefined temperature before it is send back into the cylinder. The amount of exhaust gas recirculated is calculated before it is send into the engine. The amount of exhaust gas recirculated is calculated using:

$$\%\,EGR = \frac{\text{Mass of air admitted without EGR} - \text{Mass of air admitted with EGR}}{\text{Mass of air admitted without EGR}}$$

In the present experiment the flow of the exhaust gas is controlled by a valve. The exhaust gas is recirculated into the stream of fresh air which is taken from the atmosphere through a pipe. The exhaust gas and fresh air are mixed with each other before they are send into the cylinder. Both the flow rates of the fresh air and exhaust air air are calculated using a U- tube manometer as shown in the the figure 1.

Table 1 Specifications of the Engine

ENGINE SPECIFICATIONS	
Fuel	: Diesel oil
No of cylinders	: 1
No of strokes	: 4
Bore	: 85 mm
Stroke length	: 100 mm
Engine R.P.M	: 1500 rpm
B.H.P	: 5 hp at 1500 rpm
Bsfc	: 0.28 kg/kW-hr
Calorific value	: 43000 Kcal/kg
Cooling type	: Water cooled

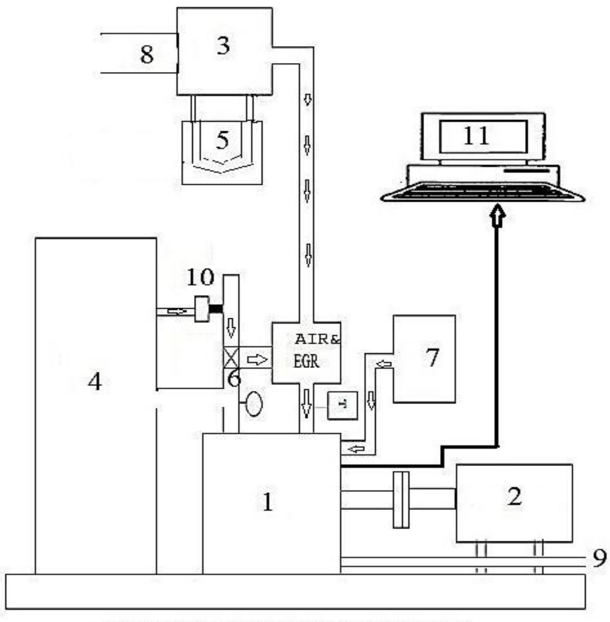

Fig 1 Experimental set-up

Experimental Procedure

The engine is operated at a constant speed of 1500 rpm with injection advance 24.9^0. Cetane improver di tert butyl peroxide was added to the diesel at a ratio of 0.5%. The first stage of experiment was performed with diesel at different loads from no-load to full load with EGR rates such as 0%, 10% and 15% at constant speed. Engine loads are adjusted by using eddy current dynamometer. Exhaust gases are tapped from exhaust pipe and connected to inlet airflow passage. So it is hot EGR. The rate of EGR is varied with the help of EGR control valve which is fixed in the pipe control. The second stage of experiment was performed with diesel at different loads from no-load to full load with EGR rates such as 0%, 10% and 15% at constant speed. Engine loads are adjusted by using eddy current dynamometer. Exhaust gases are tapped from exhaust pipe and they are stored in a drum for a certain time so as to reach the desired temperature and then connected to inlet airflow passage. So it is cold EGR.

Results and Discussion

Performance Analysis

Brake Thermal Efficiency (BTE)

Results obtained by performing the experiment are presented in the graphical form as shown in the below graphs. The variation of the brake thermal efficiency along the different loads is presented in graph by taking load on X axis and BTE on Y axis as shown in figure 2. It is evident from the graph that the brake thermal efficiency increases with the load and the maximum possible brake thermal efficiency will be at the maximum load. There is a slight increase in brake thermal efficiency as the EGR rate is increased. 10 % Cold EGR shows higher efficiency when the engine is running at partial loads. But when it comes to 15 % EGR, hot EGR has the higher efficiency at higher loads due to the fact that when inlet temperatures are high, ic engines will have the higher efficiency. The other reason for this is that higher intake charge temperature increases the combustion velocity which leads to decrease in lead time thereby increasing the brake thermal efficiency. But the increase in brake thermal efficiency is marginal. Higher EGR rates would reduce the brake thermal efficiency.

Brake Specific Fuel Consumption

The variation of the brake specific fuel consumption (BSFC) along the different loads is presented in graph by taking load on X axis and BSFC on Y axis as shown in figure 3. It can be observed from the graph that brake specific fuel consumption decreases as the load increases. As the EGR rate is increased the brake specific fuel consumption gets reduced and diesel without EGR has the higher specific fuel consumption.

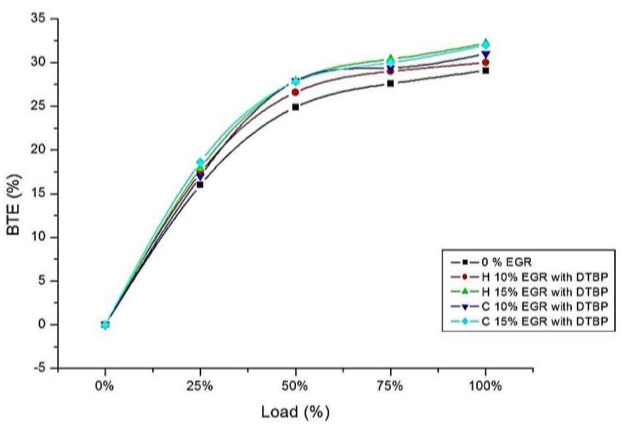

Fig. 2 Variation of Brake Thermal Efficiency with load for different percentages of cold and hot EGR

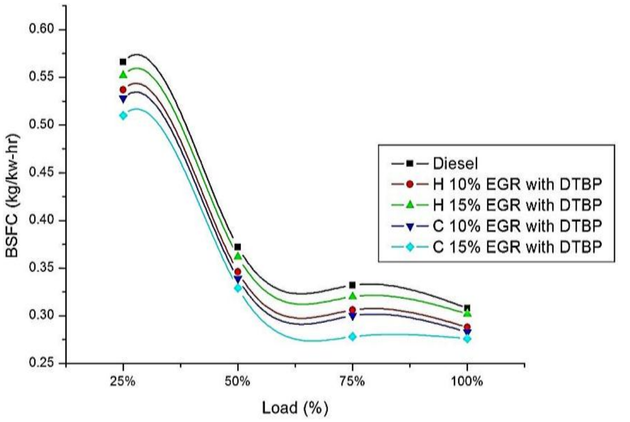

Fig. 3 Variation of Brake Specific Fuel Consumption with load for different percentages of cold and hot EGR\

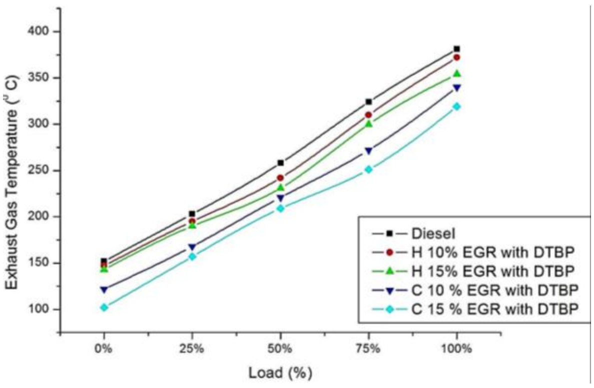

Fig. 4 Variation of Exhaust Gas temperature with load for different percentages of cold and hot EGR

Exhaust Gas Temperature

The variation of the Exhaust gas temperature (EGT) along the different loads is presented in graph by taking load on X axis and EGT on Y axis as shown in figure 4. It is clear that important reason for formation of NOx in the combustion chamber is extremely high temperature. The above graph indicates that as we increase the EGR rate the exhaust gas temperature reduces. So it can be concluded that the combustion chamber temperature also reduces and thus the formation of Nox also reduces. The cold EGR has a significant effect on the exhaust gas temperature.

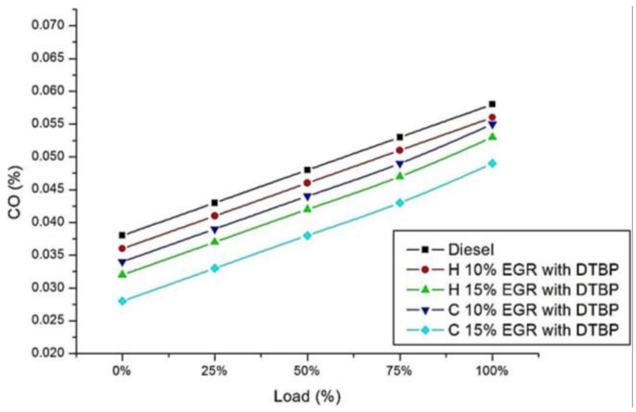

Fig. 5 Variation of CO Emissions with load for different percentages of cold and hot EGR

Co Emissions

The variation of the CO emissions along the different loads is presented in graph by taking load on X axis and CO on Y axis as shown in figure 5

The figure shows the increase of Co emissions as the load increases. As the EGR rate is increased Co emissions also gets reduced to a greater extent. This can be attributed to the reduction of available oxygen to combine with carbon.

NOx Emissions

The variation of the NOx emissions along the different loads is presented in graph by taking load on X axis and NOx on Y axis as shown in figure 6

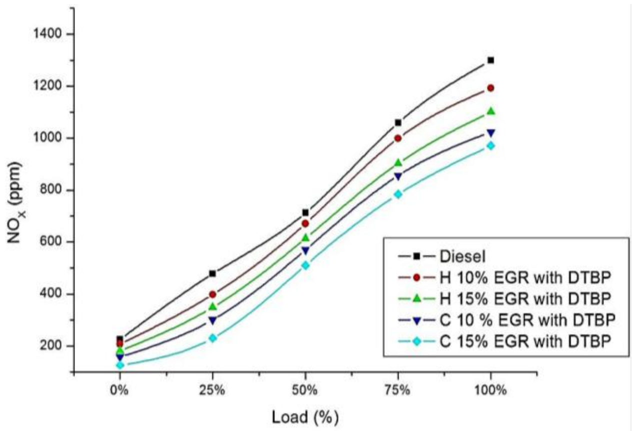

Fig. 6 Variation of NOx Emissions with load for different percentages of cold and hot EGR

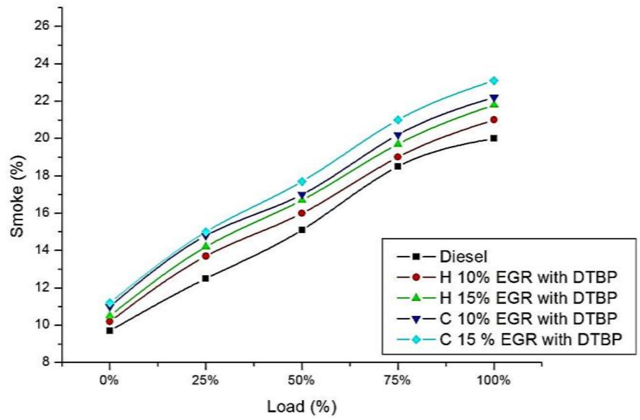

Fig. 7 Variation of smoke with load for different percentages of cold and hot EGR

The significant combined effect of EGR and cetane improver can be found in NOx emissions. The reason for reduction in NO_x with EGR is the reduction of combustion temperature as a result of the addition of exhaust gases to the intake air which reduces the combustion temperature. Still higher EGR rates are able to reduce NO_x emissions by a large amount, which however is accompanied by a reduction in BTE. There NOx reduces about 42% when engine run at full load.

Smoke

The variation of the smoke along the different loads is presented in graph by taking load on X axis and smoke on Y axis as shown in figure 7.

The smoke increases slightly as the EGR rates increases. This is because of the recirculation of exhaust gases into the cylinder. The effect of cold and hot EGR is insignificant in case of smoke opacity.

Conclusions

The following conclusions can be derived from the present experimental investigation,

1. The effect of EGR along with cetane improver can be found predominant in reduction of NO_X emissions.
2. When we compare the hot EGR and cold EGR, Cold EGR has the greater advantage if is well designed. A well designed heat exchanger could have a greater impact on the engine.
3. The addition of cetane improver has a significant effect in reduction of all the emissions.
4. The addition of cetane improver reduces the brake specific fuel consumption significantly.
5. There is a significant increase in efficiency of engine due to EGR.
6. When we utilize biodiesel as fuel, there is a problem with increase in NO_X emissions as well as there will be reduction in performance of the engine. But if EGR technique is incorporated with the biodiesel, then there will be greater advantage of increasing the performance of engine as well as reduction in all the emissions.
7. Co emissions reduce significantly with the addition of cetane improver.
8. Smoke increases slightly with increase in percentage of EGR.

So taking all the results into consideration from the present experimentation, Cold EGR with 15% exhaust gas recirculation along with 0.5% cetane improver added to fuel would result in optimum engine performance as well as greater reduction of emissions.

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