Effect of Exhaust Gas Recirculation (EGR) on C.I. engine performance and emission - A review

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ABSTRACT : **Biodiesel is obtained from vegetable oils throughout transesterification process. There are many advantages of biodiesel but it leads to high NOx emission. In order to reduce NOx emission from the engine, it is necessary to keep max out combustion temperature under control. EGR technique is used to reduce NOx emission as it enables lesser flame temperature and oxygen concentration in combustion chamber. At near emission norms becomes harsh for any I.C. Engine. The chief pollutant are NOx, PM, CO, HC, soot, etc from which NOx are very harmfull component. It is possible to limit the negative effect of NOx on the environment by a variety of methods such as catalyst, water injection and exhaust gas recirculation. The purpose of this work is to study the effect of exhaust gas recirculation (EGR) on the NOx emission from engine exhaust. Cooled exhaust gas recirculation (EGR) is a general way to control the NOx generation. It was found that adding exhaust gas to the fresh air charge will advantageous to reduce the NOx emission considerably. Reductions in NOx emission are achieved by earlier investigators with 10% to 30% EGR. However, EGR has other effects on emission production and combustion that are decrease in peak temperature, delay in heat release, and Oxygen concentration in cylinder charge and reduce the air-fuel ratio.**

Index terms : **Biodiesel, CI Engine, EGR, Transesterification.**

1. INTRODUCTION

Even though diesel engines have advantages they produce higher levels of NOx and smoke emissions which have important effect on human health and welfare. The investigate for energy independence and concern for a cleaner environment have created important interest in biodiesel, despite its shortcoming. Biodiesel is an diesel fuel which can be obtained from the transesterification of vegetable oils. The use of biodiesel in diesel engines does not require any modification in engine. An important property of biodiesel is its oxygen content which is usually not contained in diesel fuel. Biodiesel gives considerably less emissions of PM, carbon monoxide (CO) and hydrocarbon (HC) without. Exhaust gas recirculation (EGR) can be used in the diesel engines. EGR is an effective method of dropping NOx emissions from the diesel engine exhaust.

1.1 Exhaust gas recirculation (EGR) [1, 2]

As a substitute of using after treatment systems to comply with exhaust emission norms, it is also possible to reduce the formation of emissions at the time of combustion. The raw emissions are reduced and thus no after treatment is needed. It is ordinary practice nowadays, to use EGR to reduce the formation of NOX emissions. A part of the exhaust gases is recalculated into the combustion chambers. This can be achieved by arrangment shown in figure. The principle of EGR is to recirculate the exhaust gases back into the inlet manifold where it mixes with the fresh air.

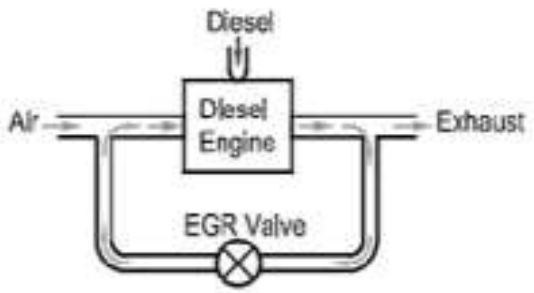

Fig.1. Exhaust Gas Recirculation

The exhaust gas acts like inert gas in the combustion chamber, it does not contribute in the combustion reaction. This leads to decrease the peak combustion temperature by different effects. The fuel molecules need extra time to combine with oxygen molecule, as there are inert molecules around.

The energy is also used to heat up a larger gas part than it would without EGR. As the air is mixed with exhaust gas, the mass of a gas part contain the required amount of oxygen gets larger. One more effect is the change in heat capacity. Exhaust gas has a more specific heat capacity than air. So for the same amount of combustion energy a gas mass containing EGR will get a less peak temperature than pure air. The lower combustion temperature directly reduces the NOX formation, as the NOX formation rate is highly temperature dependent.

EGR ratio is defined as the ratio of mass of recycled gases to the mass of engine intake. Also %EGR is

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

About 15% recycle of exhaust gas will decrease NOX emission by about 80%. It should be noted that NOX emission occurs through lean mixture limits when exhaust gas recirculation is least effective.

From above methods, EGR is the most efficient and widely used system to control the development of oxides of nitrogen in I.C. engine. The exhaust gas which is sent into the combustion chamber has to be cooled to improve the volumetric efficiency of the engine . The exhaust gas for recirculation is sucked and passed through control valves to control the exhaust gas recirculated. Exhaust gas recirculation is off during idle to avoid rough engine operation.

1.2 Classification of EGR systems [1, 2]

Various EGR systems have been classified on basis of EGR temperature, configuration and pressure.

1.2.1 Classification based on temperature

I. Hot EGR: Exhaust gas is recirculated without being cooled, resulting in enhanced intake charge temperature.

II. Fully cooed EGR: Exhaust gas is fully cooled before mixing with in take air using water cooled heat exchanger. In this case the moisture present in the exhaust gas may condense and the resulting water droplets may cause unwanted effects inside the engine cylinder.

III. Partly cooled EGR: To avoid water condensation the temperature of the exhaust gas in kept just above its dew point temperature.

1.2.2 Classification based on pressure

I. Low pressure EGR system

The implementation of EGR is straight forward for naturally aspirated engines because the exhaust tail pipe back pressure is normally higher than the intake pressure. If part of turbine outlet exhaust gas is supplied to compressor inlet through the flow control valve then it called low pressure EGR loop. In low pressure EGR system, a flow passage is a provided between the exhaust of super charger turbine and the intake manifolds coupled to the super charging compressor. The EGR flow is regulated with a throttling valve showing in Fig. The pressure differences generally are enough to drive the EGR flow of a desired amount except through idling..

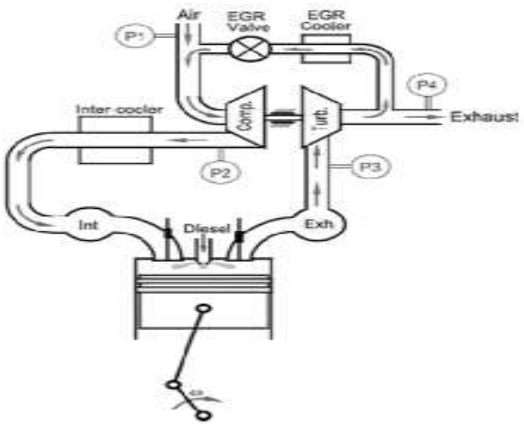

Fig. 2. Low Pressure EGR loop

The low pressure EGR is not applicable as the conventional compressor and inter–coolers are not designed to make sure the temperature of exhaust gas. It is found that by using low pressure EGR is feasible up to high load region with significant reduction in NOX however some problem occurs which influence durability, high compressor outlet temperature and intercooler clogging.

II. High pressure EGR system

Another way of EGR is high pressure EGR loop. In high pressure EGR system, a flow passage is a devised between the exhaust of engine (up-stream of the turbine) and the intake manifolds of engine (downstream of the super charging compressor). In this system the exhaust gas is recirculated from upstream of the turbine to downstream of compressor as shown in Fig 3. Therefore compressor and inter-cooler are not exposed to the exhaust gas. Such high pressure loop EGR system is only related when the turbine upstream pressure is suitably higher than the boost pressure (compressor downstream pressure) i.e. if (p3-p2)>0.

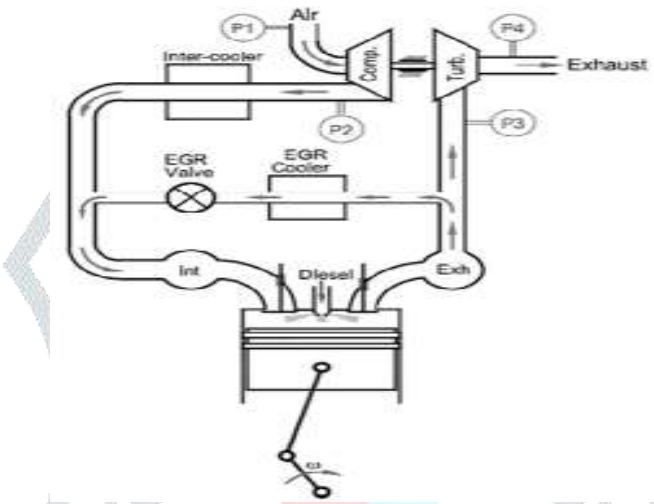

Fig.3. High Pressure EGR Loop

In this system even if EGR is possible in the high load region the excess air ratio decreases and fuel consumption increases remarkably.

2. LITERATURE REVIEW

Masjuki H. Hassanet al [3] in this research universal Biofuel scenario is assessed by Biofuel policies and standards. Different Biofuel processing methods are also summarized. Some strategy on dedicated Biofuel engine are prescribed. Kaushik Ranjan Bandyopadhyay [4] studied the research work in several areas and presented a report called Policy Brief in which he focused on Environmental and Social Sustainability of Biofuel as well as Biofuel promotion in India for transport.

Rizwana Naureen et al [5] studied transesterification of sunflower oil using alkali-catalyzed methanolysis and Fuel properties of biodiesel were determined with the help of standard tests, and it was found that biodiesel properties were very near to diesel fuel specifications. Dongsheng Wen et al [6] This paper reviews state-of-the-art application of the supercritical fluid (SCF) method in biofuels production that includes biodiesel from vegetable oils via the transesterification process, bio-oil from the liquefaction of biomass, with biodiesel production as the main focus and bio-hydrogen from the gasification. The global biofuel situation and economics are also reviewed.

Jinlin Xuea et al [7] In this work, reports about biodiesel engine performances and emissions, published by journals in scientific indexes, were cited preferentially since 2000 year. From these reports, the effect of biodiesel on engine power, economy, durability and emissions counting regulated and non-regulated emissions, and the corresponding effect factors are surveyed and analyzed in detail. Wail M.et al [8] in this study, the combustion and emissions characteristics of compression ignition engine were measured using a biodiesel as a fuel. The tests were performed on a four stroke single cylinder CI engine loaded at variable engine speed in between 1200-2600 rpm.

K. Nantha Gopal et al [9] In the present study, in-depth research and comparative study on blends of biodiesel made from WCO and diesel is done to bring out the benefits of its general usage in CI engines. The experimental results of the study show that the WCO biodiesel has similar characteristics as that of diesel. The brake thermal efficiency, unburned hydrocarbon, carbon

monoxide and smoke opacity are decreased in the case of WCO biodiesel blends. On the other hand specific energy expenditure and oxides of nitrogen of WCO biodiesel blends are found to be more than diesel.

Corsini, A et al [10] in these work different vegetable oils (both straight and waste) are used to fuel a DE in automotive configuration and study its behaviour. Tests are carried out using a turbocharged, four stroke, four cylinders, water cooled, common-rail multi jet DE. The influence of fuel used on engine power, specific consumption and efficiency, are compared with Diesel fuel. his results shows that power loss due to the use of RO and BD is relevant mainly at low loads (ranging from 18 to 22 %). At higher loads the three fuels show a similar behavior up to about 2800 rpm, than BD gives a larger power output. And Pollutant emissions are comparable to or less than those of DF, apart from HC emission from RO which reaches the highest level

Simon Reifarthit [11] It gives an overview of the EGR and diesel combustion. This work provides a comparison of different EGR systems, such as short-route EGR, long-route EGR, , hybrid EGR, and a system with an EGR pump. Both the steady-state and transient performance are compared.

Jaffar Hussain et al [12] studied the effect of EGR on performance and emission characteristic of a three cylinders, air cooled and constant speed direct injection diesel engine, which is usually used in agricultural farm machinery. Such engines are normally not operated with EGR. The experiments were performed to experimentally evaluate the performance and emissions for different EGR rates of the engine. his results are as sown in figure..

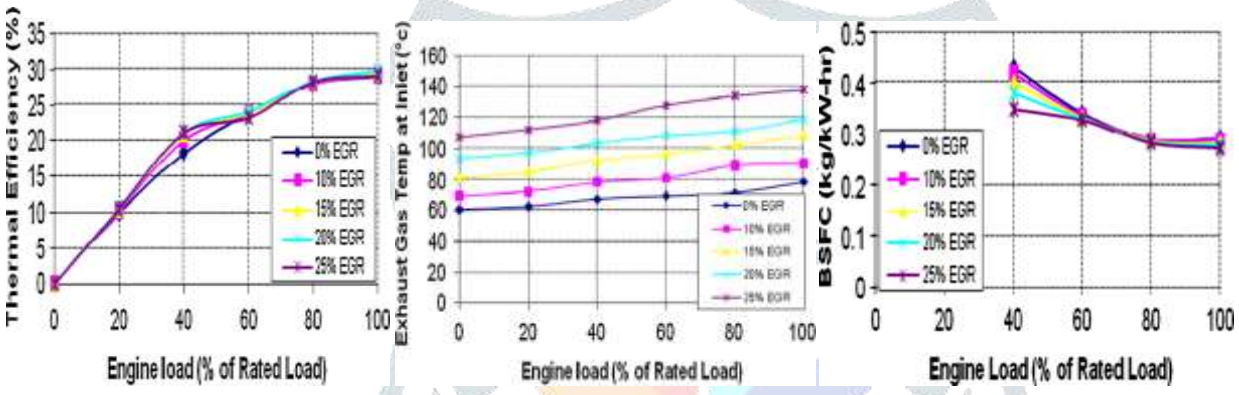

Fig.4 Effect of EGR on engine performance

Thermal efficiency is found to have slightly increased with EGR at lower engine loads 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. Exhaust gas temperature drops with increase in EGR rate. The reasons for reduction of temperature are less availability of oxygen and higher specific heat of recirculated and fresh air mixture as explained earlier.

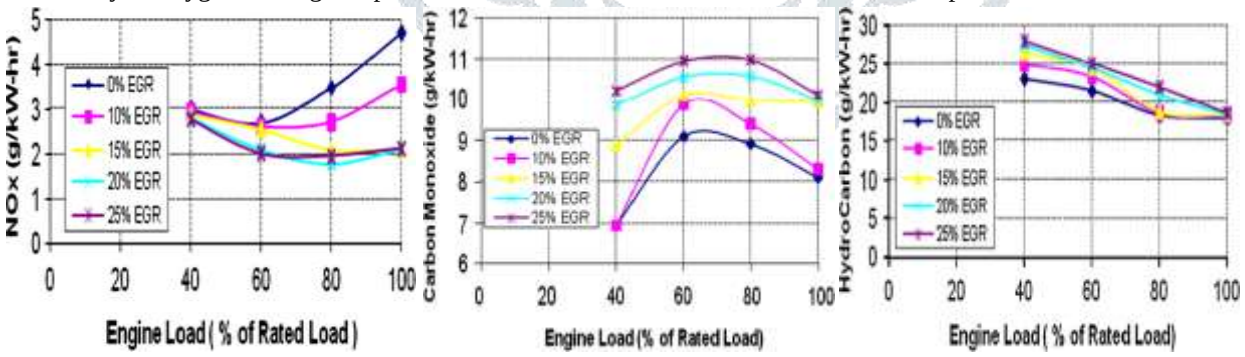

Fig.5 Effect of EGR on emissions

Emission graphs show that HC and CO emissions are increases with increasing EGR. HC and CO emission increases due to lower oxygen concentration which results in rich air–fuel mixtures and incomplete combustion. The degree of reduction in NO_X at higher loads is higher. The reduction in NO_X emissions using EGR is observed due to oxygen concentration and decreased flame temperatures in the combustible mixture. At the part load, O_2 is available in sufficient quantity but at high loads, O_2 reduces drastically, therefore NO_X reduction more at high loads compared to low loads.

B. Jothithirumal et al [13] conducted experiment on the effect of exhaust gas recirculation on the exhaust gas temperature. The experimental set up for proposed experiments was developed on two cylinder direct injection air cooled compression ignition engine experiment was conducted for observing the effect of different quantities of EGR on exhaust gas temperature he concluded that optimum results are obtained at 25% EGR opening. At this percentage NO_x level decreases where as PM and HC emission decreases. There is appreciable change in CO emission and thermal efficiency.

Deepak Agarwal et al [14] conducted a test on a single cylinder DI diesel engine and calculated the performance and emission characteristics with methyl ester of rice bran and its blends as fuel with EGR system. Based on the above engine tests, he concluded biodiesel and EGR both can be employed together in CI engines to obtain reduction of NOx and smoke. Other emissions such as HC and CO are also found to have decreased. At 20% biodiesel blend with 15% EGR is improves the thermal efficiency, reduces the exhaust emissions and the BSEC.

3. CONCLUSIONS

EGR is a very useful method for dropping the NOx emission. EGR displaces oxygen in the intake air and dilute the intake charge by recirculating exhaust gas in to the combustion chamber. Recirculated exhaust gas lower the oxygen concentration in combustion chamber and raise the specific heat of the intake air mixture, which results in lower flame temperatures. It was seen that 15% EGR rate is found to be effective to reduce NOx emission substantially without deteriorating performance of engine in terms of brake thermal efficiency, BSFC and emissions. It can be concluded that higher EGR rates can be applied at lower loads and lower EGR rates can be applied at higher load. EGR can be applied to diesel engine fuelled with diesel , bio-diesel, LPG, etc to reduce NOx emission without sacrificing its efficiency and fuel economy.

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