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Review on Effect of Exhaust Gas Recirculation (EGR) on Nox Emission from C.I. Engine

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ABSTRACT

Biodiesel is derived from vegetable oils or animal fats throughout transesterification process. There are many advantages of biodiesel but it is not so popular because of 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 one of the method to reduce NOx emission as it enable lesser flame temperature and oxygen concentration in combustion chamber. At near emission norms becomes harsh for any I.C. Engine. The chief pollutant are CO, HC, NOx, PM, soot, etc from which NOx are one of the most injurious component. It is possible to limit the negative effect of NOx on the environment by a variety of methods like exhaust gas recirculation (EGR), catalyst and water injection. The aim of this work is to review the effect of exhaust gas recirculation (EGR) to reduce the NOx emission from tailpipe of homogeneous charged C.I. engines. Cooled exhaust gas recirculation (EGR) is a general way to control the NOx generation in engine cylinder. It was found that adding EGR to the fresh air charge to homogeneous charged engines will advantageous to reduce the NOx emission substantially. Substantial reductions in NOx emission are achieved by earlier investigators with 10% to 30% EGR. However, EGR has other effects on combustion and emission production that are increase of intake charge temperature, delay in heat release, reduce of peak cylinder temperature and decrease in O_2 concentration in cylinder charge and reduce the air-fuel ratio.

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I. INTRODUCTION

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

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

As a substitute of using after treatment systems to comply with exhaust emission legislation, it is also possible to avoid the formation of emissions during the 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 either internally with the proper valve timing, or externally with some kind of piping, Figure shows this schematically. The principle of EGR is to recirculate about 10% to 30% of the exhaust gases back into the inlet manifold where it mixes with the fresh air.

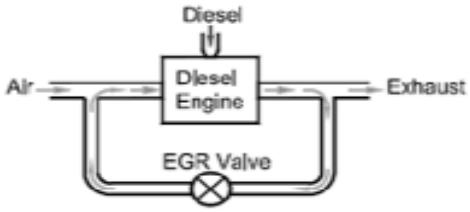

Fig.1. Exhaust Gas Recirculation

The exhaust gas acts as an inert gas in the combustion chamber, it does not contribute in the combustion reaction. This leads to a reduction of the combustion temperature by different effects. The fuel molecules need extra time to find oxygen molecule to react with, as there are inert molecules around. This minimises the combustion speed and thus reduces the peak combustion temperature, as the same amount of energy is released over a longer period of time.

The energy is also used to heat up a larger gas part than it would without EGR. As the air is diluted 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 higher specific heat capacity than air, due to the CO_2- molecule's higher degree of freedom. So for the same amount of combustion energy a gas mass containing EGR will get a lower 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

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

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 inside the combustion chamber of I.C. engine. The exhaust gas which is sent into the combustion chamber has to be cooled so that the volumetric efficiency of the engine can be improved. The exhaust gas for recirculation is sucked through an orifice and passed throughout control valves for regulation of the quantity of recirculation. Normally exhaust gas recirculation is shut off during idle to avoid rough engine operation.

1.11 Classification of EGR systems [1, 2]

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

1.11.1 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 in full cooled before mixing with fresh 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.

1.11.2 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 delivered 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 devised between the exhaust of super charger turbine and the intake manifolds coupled to the super charging compressor. The flow of EGR 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.

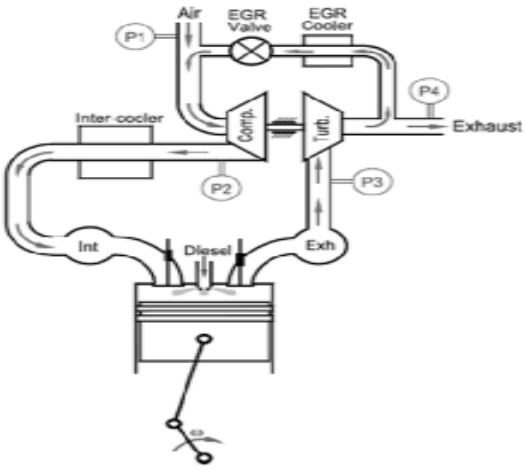

Fig. 2. Low Pressure EGR loop

The low pressure EGR loop 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 the compressor or the downstream of the inter-cooler as shown in Fig. The compressor and inter-cooler are therefore 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.

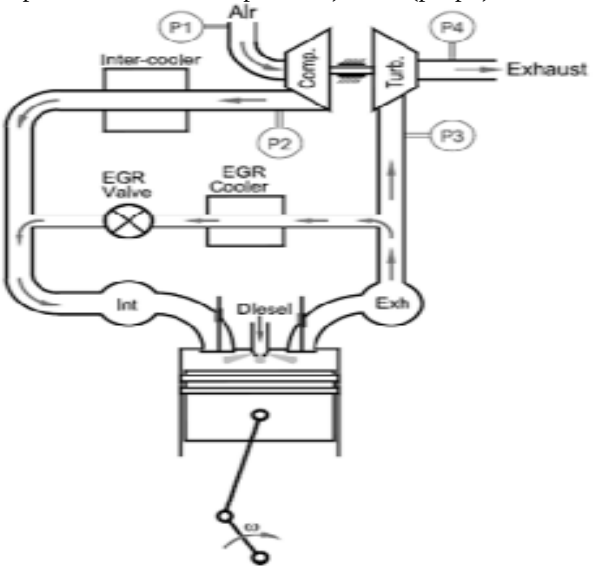

Fig.3. High Pressure EGR Loop

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

II. 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-hydrogen from the gasification and bio-oil from the liquefaction of biomass, with biodiesel production as the main focus. The global biofuel situation and biofuel economics are also reviewed.

Jinlin Xuea et al [7] In this work, reports about biodiesel engine performances and emissions, published by highly rated 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 characteristics and emissions of compression ignition diesel engine were measured using a biodiesel as an alternative fuel. The tests were performed at steady state conditions for a four stroke single cylinder diesel engine loaded at variable engine speed between 1200-2600 rpm.

K. Nantha Gopal et al [9] In the present study, in-depth research and comparative study of blends of biodiesel made from WCO and diesel is carried out to bring out the benefits of its general usage in CI engines. The experimental results of the study reveal that the WCO biodiesel has similar characteristics to that of diesel. The brake thermal efficiency, carbon monoxide, unburned hydrocarbon and smoke opacity are observed to be lower in the case of WCO biodiesel blends than diesel. On the other hand specific energy expenditure and oxides of nitrogen of WCO biodiesel blends are found to be higher 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, efficiency, and exhaust opacity, are compared with those obtained fuelling with Diesel fuel.

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

Jaffar Hussain et al [12 studied the effect of EGR on performance and emissions in 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.

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.

Deepak Agarwal et al [14] conducted a test on a single cylinder DI diesel engine and calculated the performance and emission characteristics with rice bran methyl ester (RBME) and its blends as fuel with EGR system. They optimized and reported that 20% biodiesel blends with 15% EGR produce less NOx, CO and HC emissions and also enhanced thermal efficiency and reduced BSFC.

B. Deet al [15] In this paper an experimental study is carried out on an I.C. engine laboratory single cylinder, four-stroke VCR, direct injection diesel engine to analyze the performance and emission characteristics of pure diesel, Jatropha oil and Jatropha oil-diesel blended fuels with different blended rates. The measurements are recorded for the compression ratio of 16, 17 and 18 varying the load

from idle to rated load of 3.7 kW. Comparative results are given at constant engine speed, variable compression ratio and various engine loads for pure diesel, Jatropha oil and Jatropha oil-diesel blended fuels revealing the effect of diesel, Jatropha oil and Jatropha- diesel blended fuels combustion on engine performance and exhaust emissions.

III.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 exhaust gas recirculated 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 engine performance in terms of thermal efficiency, bsfc and emissions. Thus, it can be concluded that higher rate of EGR can be applied at lower loads and lower rate of EGR can be applied at higher load. EGR can be applied to diesel engine fuelled with diesel oil, bio-diesel, LPG, hydrogen, etc without sacrificing its efficiency and fuel economy and NOx reduction can thus be achieved.

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