EFFECT OF CATALYTIC CONVERTER AND EGR SYSTEM ON EMISSION CHARACTERISTIC OF IC ENGINE

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ABSTRACT

In present, fuel consumption and exhaust emission of a IC engine is very important to improve. Now days, various technologies are used to improve the emission characteristics of IC engine. Exhaust gases which are emitted from IC engine consists of CO, HC, PM, COx, NOx etc. this paper tries to present a review about the effect of EGR system and catalytic converter to improve the emission characteristics of IC engine. In IC engine NO_x *emission is a critical issue and EGR system is developed to reduce this* NO_x *emission very efficiently.*

Keywords: EGR, IC Engine, Catalytic converter.

I. INTRODUCTION

In present, an emission characteristic of IC engine is a very critical issue. Exhaust gases, which are emitted from IC engine consists of HC, CO_X , NO_X ,PM etc. therefore engine designer have to develop technologies to reduce emission pollutants as well as fuel consumption.EGR system and catalytic converter are used to reduce the exhaust emission from an IC engine. Catalytic converter reduces efficiently the emission of HC, CO, PM etc. whereas EGR system is a very effective technique to reduce NO_X emission. 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 2000K will be able to reduce the NOx formation [1], and to reduce this temperature EGR system is used. In EGR system exhaust gases, which are emitted from the IC engine is mixed to the intake air, which reduces the amount of oxygen for combustion. Therefore reduction in flame temperature in the combustion chamber. Thus combination of lower oxygen quantity in the intake air and reduced flame temperature reduces rate of NOx formation reactions [2, 3]. Catalytic converter is also used to reduce the exhaust emission from an IC engine.

EGR	Exhaust Gas Re-circulation
CI	Compression Ignition
IC	Internal Combustion
PM	Particulate Matter
NOx	Oxides of Nitrogen
HC	Hydro Carbons

II.EGR SYSTEM

EGR system is an effective technique to reduce the exhaust emission mainly NOx formation from an IC engine. The engines using EGR emit lower quantity of exhaust gases compared to non-EGR engines because part of the exhaust gas is re-circulated [4]. Percentage of EGR can be find as follows [1]

$$\%EGR = \frac{Volume of EGR}{Total\ intake\ charge\ into\ the\ cylinder} x100$$

Another way to define the EGR ratio is by the use of CO_2 concentration (Baert et al 1999),

$$EGR = \frac{[CO_2]_{intake} - [CO_2]_{ambient}}{[CO_2]_{exhaust} - [CO_2]_{ambient}}$$

A major hurdle in understanding the mechanism of formation and controlling its emission is that combustion is highly heterogeneous and transient in diesel engine. While NO and NO_2 are lumped together NO_x, there are some distinctive differences between with two pollutants. NO is colorless and odourless gas, while NO_2 is a reddish brown gas with pungent odour. Both gases are considered toxic, but NO_2 has a level of toxicity five times greater than that of NO. Although NO_2 is largely formed from oxidation of NO, attention has been given on how NO can be controlled before and after combustion (Levendis et al 1994) [1].

To reduce the NO_X emission exhaust gases are re-circulated to the combustion chamber with intake air, this reduces the oxygen concentration for combustion and reduces the temperature in the combustion chamber. therefore reduces the NO_X emission very effectively. at higher loads, the oxygen in exhaust gas becomes scarce and the inert constituents start dominating along with increased exhaust temperature. Thus, as load increases, diesel engines tend to generate more smoke because of reduced availability of oxygen [5]. Wagner et al. tried to achieve lower emission of NOx and soot using highly diluted intake mixture. At very high EGR rate (around 44%), PM emission decreased sharply with a continuous drop in NOx emission but this high EGR rate significantly affect the fuel economy [6]. EGR system is used in CI engine to reduce regulations with competitive fuel economy, exhaust gas after-treatment and optimized combustion is necessary. However, it is still unresolved which concept will succeed considering production and economic feasibility [7].

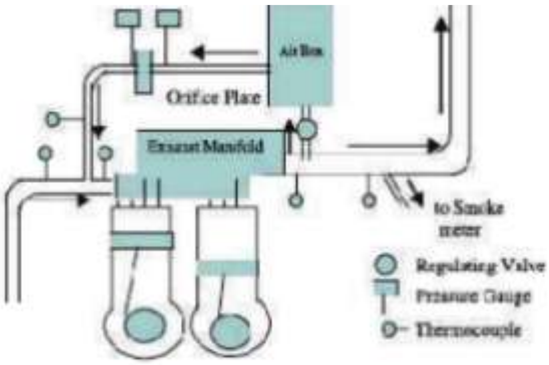


Fig. 1 IC engine with EGR system [1]

Diesel engines are assumed as a good alternative to gasoline engines because they produce lower amount of emissions [8].On the other hand, higher emissions of oxides of nitrogen (NO_x) and particulate matter (PM) have been noticed as major problems. Although, major constituents of diesel exhaust include carbon dioxide (CO_2), water vapor (H_2O), nitrogen (N_2), and oxygen (O_2), carbon monoxide (CO), hydrocarbons (HC), oxides of nitrogen (NO_x), and particulate matter (PM) are present in smaller but environmentally significant quantities [9]. In modern diesel engines, first four species normally consist of more than 99% exhaust, while last four (the harmful pollutants) account for less than 1% exhaust [10]. The ratio of NO_2 and NO in diesel engine exhaust is quite small, but NO gets quickly oxidized in the environment, forming NO_2 [11]. Since diesel engine mainly emits NO hence attention has been given to reduce the NO formation [12]. At different EGR rates Fig.2, 3, 4 and 5 shows the emission of HC, CO, NO_x and smoke respectively [9].

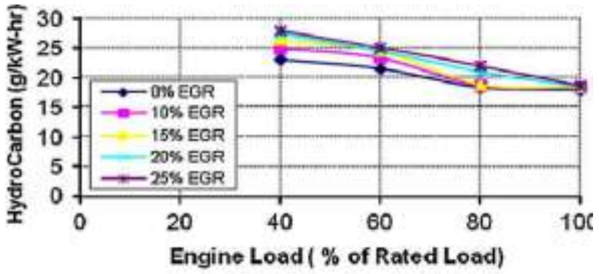


Fig. 2 HC for different EGR rates

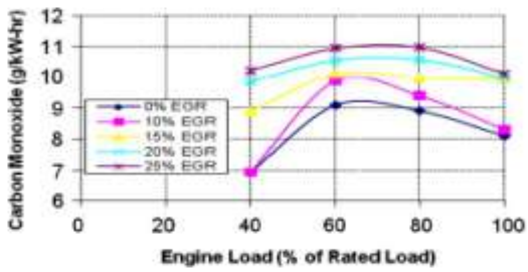


Fig. 3 CO for different EGR rates

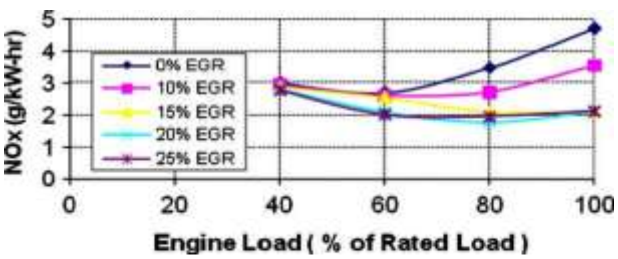


Fig. 4 NO_x for different EGR rates.

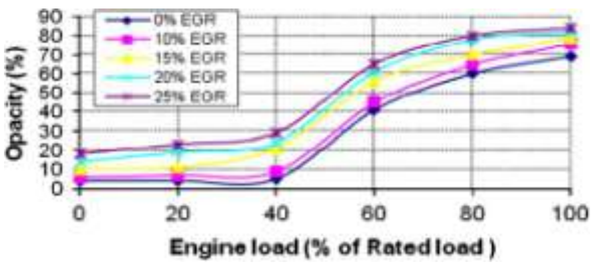


Fig. 5 Smoke at different EGR rates

Effect of EGR on unburned hydrocarbon (HC) and carbon monoxide (CO) are shown in Figs. 2 and 3, 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, and carbon monoxide emissions. At part loads, lean mixtures are harder to ignite because of heterogeneous mixture and produce higher amount of HC and CO. Fig. 4 shows the main benefit of EGR in reducing NOx emissions from diesel engine. The degree of reduction in NOx at higher loads is higher. The reasons for reduction in NOx 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 NOx is reduced more at higher loads compared to part loads [9].

Wagner et al. tried to achieve lower emission of NO_x and soot using highly diluted intake mixture. At very high EGR rate (around 44%), PM emission decreased sharply with a continuous drop in NO_x emission but this high EGR rate significantly affect the fuel economy [13]. Sasaki et al. conducted experiments using EGR on direct injection gasoline engine and reported that an appropriate volume of EGR improves fuel economy and HC emissions. This phenomenon was presumably due to the intake temperature increase by EGR, which improved the flame propagation in the relatively lean region of the air–fuel mixture, which is non-uniformly distributed [14]. Kusaka et al. also found that at low loads, EGR combined with intake heating can favorably reduce HC emission with improvement in thermal efficiency [15]. EGR was also used in a direct injection spark ignition engine as an effective way for improving fuel economy [16, 17]. Das et al. used EGR to reduce NO_x emissions in hydrogen – supplemented SI engine without any undesirable combustion phenomena [18]. Sato et al. performed experiments using methanol in direct injection compression ignition engine and found that combustion performance becomes inferior under light load conditions because temperature in combustion chamber fell due to very high latent heat of methanol, thus hampering formation of combustible air–fuel mixture [19].

Catalytic converter- catalytic converter is also a technique to reduce the exhaust emission of IC engine. The gaseous pollutants from engine exhaust can be reduced either by thermal or catalytic system. In order to oxidise HC and CO gases using thermal system, a residence time of greater than 50 ms and temperature excess of 600◦C to 700◦C are required [20]. Temperature high enough for some homogeneous thermal oxidation can be obtained by spark retarded (with some loss in efficiency) and insulation of the exhaust ports and manifold. The residence time can be increased by increasing the exhaust manifold volume to form a thermal reactor. However, this approach has limited application [20].

A catalytic converter is a device used to reduce the exhaust pollutant gases from an internal combustion engine. The catalytic converter is placed between engine manifold and exhaust tailpipe. Pollutant gases flowing out of the engine pass through it and undergo chemical processes by which they are converted into relatively harmless gases. Gas flows through the passages and reacts with catalyst within the porous washcoat. It can be said that a catalytic converter consists of steel cover plate or steel box, monolithic substrate (used to make tubular walls), washcoat (as binder) usually alumina on which catalyst materials like Pt, Rh, Pd, TiO2/CoO are dispersed with various ratio(s). Apart from catalyst materials, CeO2, or CeO2- ZrO2 mixed oxides are also added in the washcoat of three way catalytic (TWC) converter for improved oxygen storage capacity and thermal stability of alumina [21;22].

III. REACTION IN CATALYTIC CONVERTER

Gases from exhaust port entered into TWC is referred to as feed gases such as HC, CO, NO*X*, CO2. In the catalytic converter two chemical processes are occurred such as catalytic reduction and catalytic oxidation. In the catalytic reduction process, nitrogen oxide gives up its oxygen to form pure nitrogen. Then the free oxygen reacts with CO to form CO2 emission. In the oxidation process,

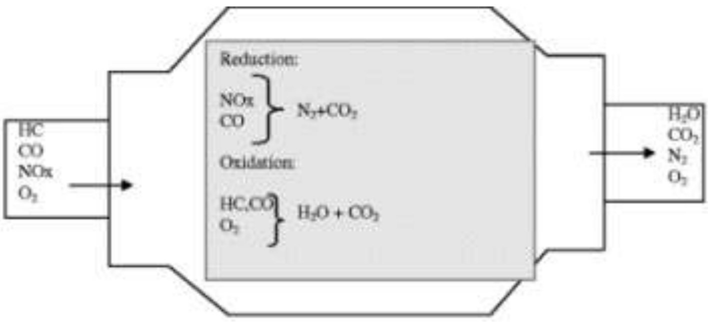
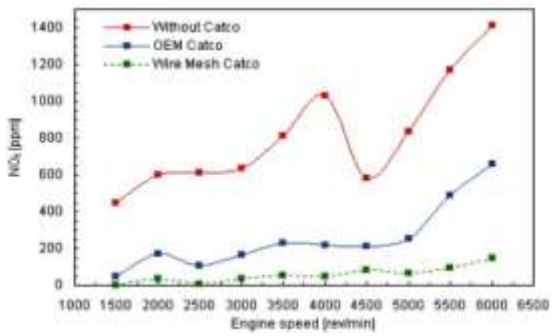


Fig.6 Oxidation and Reduction Process into Catalytic Converter [23].

hydrocarbons and carbon monoxide continue to burn. This occurs only if there is a sufficient amount of oxygen available for the hydrocarbons and carbon monoxide to form with. This chemical reaction results in oxidation of hydrocarbons and carbon monoxide to form water

(H2O) and carbon dioxide (CO2). Detailed of catalytic reduction and oxidation phenomena can be seen in figure 6 [23].



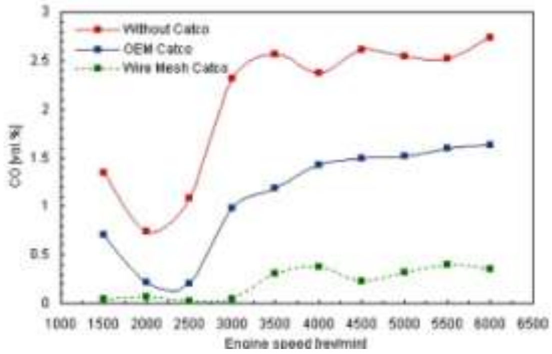


Fig. 7 Nox Emission Versus Engine Speed (With and Without Catalytic Converter) [23]

Fig. 8 CO Emission Versus Engine Speed (With and Without Catalytic Converter) [23]

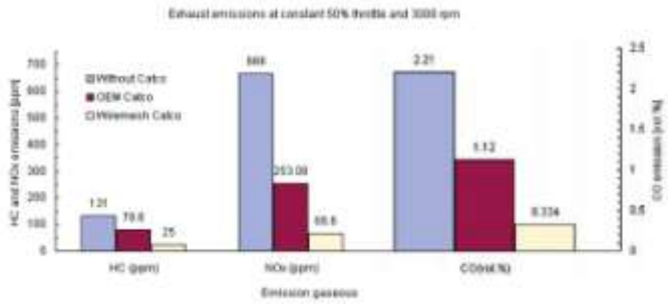


Fig. 9 HC, CO and Nox Emissions at Constant 50% Throttle and 3000 Rpm [23]

Conclusion- Exhaust emission from IC engine mainly consist of HC, CO, PM, NO_X can be reduced by the EGR system and catalytic converter. EGR system reduces NO_X formation at great extent by reducing flame temperature on combustion chamber during combustion process. The catalytic converter is also a very effective technique to reducing incomplete combustion products such as HC, CO etc. In catalytic converter oxidation and reduction of emission pollutants is taken place and the final exhaust product is converted into H_2O, CO_2, N_2, and O_2.Therefore reducing the emission pollutants in the exhaust product of IC engine.

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