A review about the effect of EGR (Exhaust Gas Re-circulation) on the emission characteristic of C.I. engine and Dual fuel engine

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Abstract-In present, developed technologies are used to reduce the fuel consumption and exhaust emission of a diesel engine. Fuel consumption in a CI engine is reduced to a considerable amount, but the emission of NO_x is a critical issue. This paper tries to present a review about the effect of EGR system on a CI engine, as well as in DF engine. EGR system is effectively reduce the NO_x emission from an engine, by reducing the amount of available oxygen and reduces the flame temperature in the combustion chamber.

Keywords-EGR system, NO_x, Diesel engine, DF engine

I. Introduction

Now a days, the stringent emission legislation are compelling the engine designer to reduce the exhaust emission by the use of developed technologies and manufacture an engine such that having low fuel consumption and very low CO_x and HC emission at high temperature but it has a considerable amount of NO_x emission at high temperature and it also emits the particulate matter (PM) with the smog. Therefore it is desirable to reduce the NO_x emission from the engine.

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].

Nomenclatures:-

EGR	Exhaust Gas Re-circulation
DF	Dual Fuel
CI	Compression Ignition
IC	Internal Combustion
PM	Particulate Matter
LPG	Liquid Petroleum Gas
HC	Hydro Carbons
A/F Ratio	Air-Fuel Ratio
NG	Natural Gas

To reduce the exhaust emission and to control effectively the NOx emission, EGR system is used. EGR system is an effective technique to control the exhaust emission. Exhaust gases from an IC engine mainly consists HC, CO, CO_x, NO_x and PM. To reduce the NO_x emission, exhaust gases are premixed during recirculation with intake air and thus reduces the available oxygen for combustion process in combustion chamber. 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 NOx formation reactions [2, 3]. To reduce the exhaust emission DF engine may be used with EGR system. A secondary fuel (such as LPG) is premixed with intake air, after the injection of diesel in the combustion chamber, which increases the flame temperature of combustion, thus lowering the emission pollutants as well as fuel consumption.

II.EGR System

In diesel engine, emission of CO and HC can be reduced by increasing flame temperature, but the NO_x

formation is increased at high temperature in the combustion chamber. To reduce the NO_x emission EGR system is used. In EGR system exhaust gases are recirculated and mixed with intake air to the combustion. Exhaust gases are displaced the fresh air and reduce the oxygen concentration and also reduces the A/F ratio. Thus result in lower flame temperature during combustion process. Due to this reduction of ignition temperature, the NO_x emission is reduced to a considerable level. 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].

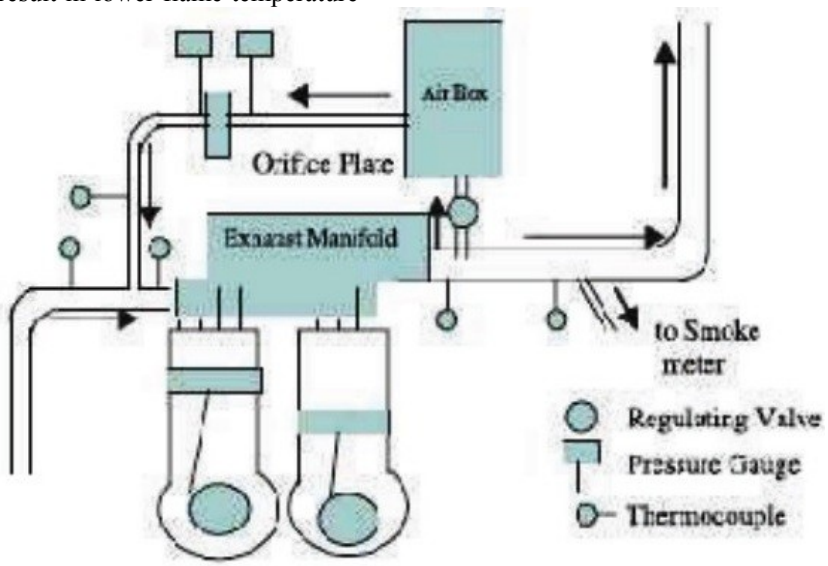

Fig. 1 IC engine with EGR system [1]

With the use of EGR, there is a trade-off between reduction in NO_x and increase in soot, CO and unburned HC_s. A large number of studies have been conduced to investigate this. It is indicated that for more than 50% EGR, particulate emissions increase significantly, therefore use of a particulate trap is recommended. The change in oxygen concentration causes change in the structure of the flame and hence changes the duration of combustion. It is suggested that flame temperature reduction is the most important factor influencing NO formation [1].

*Various EGR systems have been classified on the basis of EGR temperature, configuration and pressure [1].

1. Classification based on temperature:-
   (a) Hot EGR
   (b) Fully cooled EGR
   (c) Partly cooled EGR.
2. Classification based on configuration:-
   (a) Long route system
   (b) Short route system.
3. Classification based on pressure:-
   (a) Low pressure route system
   (b) High pressure route system.

III. CI Engine with EGR system

Diesel engines are very popular power plant used all over the world, mostly in rural areas..Diesel engine has high emission pollutants such as CO, CO_2, HC and NO_x etc. to reduce this pollutant emission mainly NO_x from diesel engine, EGR system is used along with CI engine. Diesel engines are used for bulk movement of goods, powering equipment, and to generate electricity more economically than any other device in this size range. In most of the global car markets, record diesel car sales have been observed in recent years [5]. 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 [6]. The stringent emission legislations are compelling engine manufacturers to develop technologies to combat exhaust emissions. To meet these emission regulations with competitive fuel economy, exhaust gas after-treatment and optimized combustion are necessary. However, it is still unresolved which concept will succeed considering production and economic feasibility [7].

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].

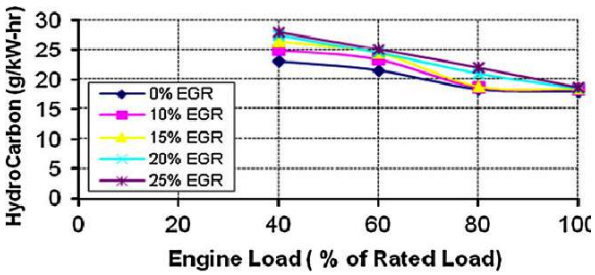

Fig. 2 HC for different EGR rates

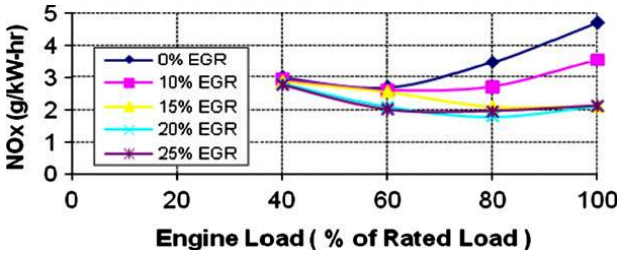

Fig. 4 NO_x for different EGR rates.

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].

NO is formed inside the combustion chamber in post-flame combustion process in the high temperature region. The NO formation and decomposition inside the combustion chamber can be described by extended Zeldovich Mechanism [13].

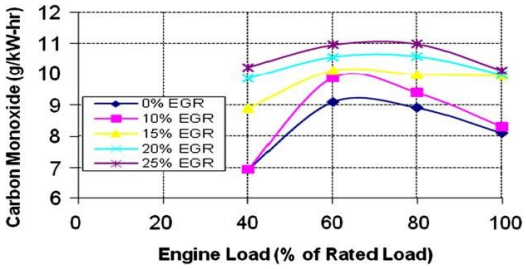

Fig. 3 CO for different EGR rates

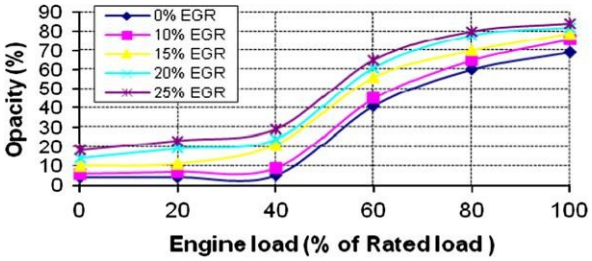

Fig. 5 Smoke at different EGR rates

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 [14]. 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 [15]. Kusaka et al. also found that at low loads, EGR combined with intake heating can favorably reduce HC emission with improvement in thermal efficiency [16]. EGR was also used in a direct injection spark ignition engine as an effective way for improving fuel economy [17, 18]. Das et al. used EGR to reduce NO_x emissions in hydrogen – supplemented SI engine without any undesirable combustion phenomena [19]. 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 [20]. At different EGR rates Fig.2, 3, 4 and 5 shows the emission of HC, CO, NO_x and smoke respectively [9].

IV. Dual fuel engine with EGR system

Dual fuel engine has high efficiency and it remains unchanged using secondary fuel, such as NG, Hydrogen and LPG. DF engine uses secondary fuel or gas at low pressure and reduces the emission due to high efficiency, clean fuel and lean burn combustion. The fuels used in DF engine are chemically stable and it may be gas or liquid and DF fuel engine also use bio-fuels. DF engine has double wall gas piping that means the engine room is a gas safe area. DF engine may use EGR system to reduce the exhaust emission.

The developments of a dual fuel injection promises the reduction of specific fuel consumption and exhaust emissions with smoke density, oxides of nitrogen emission, and better brake thermal

efficiency [21]. Oxides of nitrogen (NO_x) are formed when temperature in the combustion chamber get too hot. At 1371 ^{0}C, or hotter, the nitrogen and oxygen in the combustion chamber can chemically combine to form nitrous oxides, which, when combined with hydrocarbons (HC_s) and the presence of sunlight, produces an ugly haze in our skies known commonly as smog [22]. Thus the EGR system recycles a small amount of exhaust gas from the exhaust system (usually around 25 percent) and mixes it with the intake manifold air entering into the combustion chamber. The addition of this inert (or non-combustible) exhaust gas limits the peak combustion temperature to a range that is below 1371 ^{0}C, where the formation of nitrogen oxide (NO_x) is known to occur [23].

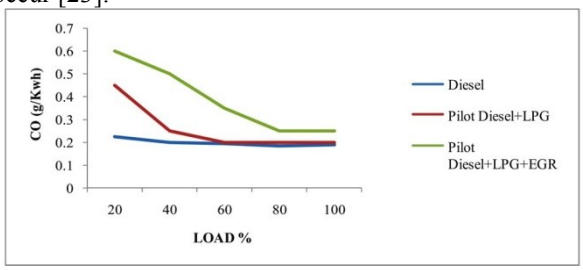

Fig. 6 CO Vs Load

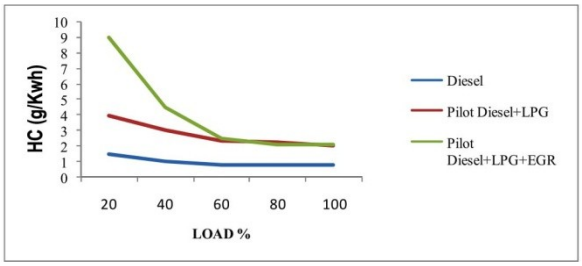

Fig. 7 HC Vs Load

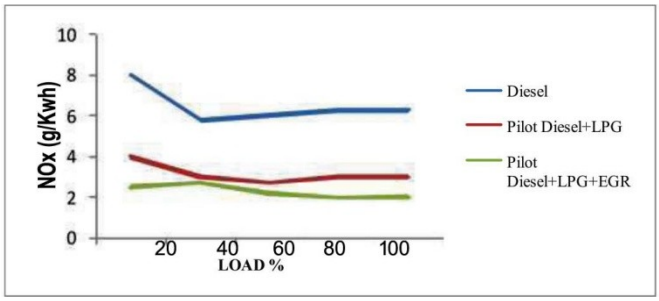

Fig. 8 NO_x Vs Load

V.CONCLUSION

Diesel engines are widely used all over the world, but the diesel exhaust contains HC, CO, CO_2, NO_x and PM. It is concluded that, EGR system is an effective system used to reduce these exhaust emission as compared to other smog control device. In diesel engines, formation of NO_x is occurred at high temperature in combustion chamber. To reduce the NO_x formation, exhaust gases are re-circulate and mixed with intake fresh air, because of this oxygen available for combustion is reduced in the combustion chamber, thus reduces the flame temperature and NOx formation.

EGR system is also used along with dual fuel engine to improve the emission characteristics as well as fuel consumption. DF engine uses diesel as pilot fuel and a secondary fuel such as LPG along with EGR system along with dual fuel engine also improves the emission characteristics of DF engine. In this technique, dual fuel engine uses diesel as primary fuel and LPG as secondary fuel. After the injection of diesel in small quantity, LPG is pre-mixed with the engine intake air, to improve the combustion process on engine and to reduce the emission pollutants during combustion. Diesel/LPG dual fuel engine improves the efficiency by 8% at 60% to 80% load condition [24]. By the increase in mixture temperature, the flame velocity is increases, thus resulting lower emission. At different loads on DF engine using EGR system Fig.6, Fig.7 and Fig.8 shows the CO, HC and NO_x emission respectively [25].

EGR system. An EGR system may be used on Diesel-LPG DF engine to reduce the emission pollutants. The CO emission is reduced throughout the engine operation with EGR gases in comparison to dual fuel mode of operation [24]. This paper work concluded that, the EGR system reduces the NO_x emission to a considerable level and 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].

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