A REVIEW ON EFFECT OF EXHAUST GAS RECIRCULATION ON NOx REDUCTION FROM CI ENGINE

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ABSTRACT

Internal combustion engine is device which converts chemical energy of fuel into mechanical energy by combustion of fuel. Due to continuous revision of emission norms for an I.C. engine, wide range of researches are going on with the focus of pollution control. NOx is one of the most harmful pollutant out of CO, HC, NOx, PM, Soot etc which are emitted by the I.C. engines. Various researches are carried out with a focus of limiting the negative effect of NOx on the environment by various methods like exhaust gas recirculation(EGR), catalyst and water injection. This work focuses on review of NOx reduction from exhaust gas recirculation method from CI engine. NOx generation in engine cylinder can be controlled by cooled exhaust gas recirculation.

Keywords: CO-carbon monoxide, HC-hydrocarbons, NO_x-nitrogen oxides, PM-Particulate matter

I.INTRODUCTION

The quest for increasing the efficiency of an internal combustion engine has been going on ever since the invention of this reliable workhorse of the automotive world. In recent times, much attention has been focused on achieving this goal by reducing energy lost to the coolant during the power stroke of the cycle. A cursory look at the internal combustion engine heat balance indicates that the input energy is divided into roughly three equal parts: energy converted to useful work, energy transferred to coolant and energy lost to exhaust. The reduction in heat losses also results in increased exhaust enthalpy. This extra exhaust energy can be utilized to drive a compounding turbine or a bottoming cycle, thus improving the overall system efficiency [1, 2].

The motivating force behind the low heat rejection (LHR) engine has been the prospect to decrease of cooling load. That system is there to keep engine-operating temperatures down to levels tolerated by currently used constructional materials and lubricants. If the energy normally rejected to the coolant could be recovered instead on the crankshaft as useful work, then a substantial improvement in fuel economy would be obtained. Increased thermal efficiency and elimination of the cooling system are the major promises of the LHR engine [3]. On the other hand, the LHR engine designs promise to meet the increasingly stringent regulations in the areas of fuel economy and permissible emissions levels [3, 4]. At the same time, exhaust energy rise, which accompanies this, can be effectively used in turbocharged engines. Higher temperatures in the combustion chamber can also have a positive effect on diesel engines, due to the self-ignition delay drop [5, 6].

Exhaust emissions and fuel economy should be considered together. The regulated emissions include unburned hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NO*x*), and exhaust particulates (or in some cases, smoke). Of these, only CO is not a potential problem for the diesel, because of the overall lean stoichiometry it employs. One might expect lower HC from LHR diesel because the shortened ignition delay associated with higher temperatures decreases to opportunity for over mixing of fuel beyond the lean combustion limit and because the generally higher cylinder-gas temperature during the expansion stroke should encourage oxidation of any unburned fuel escaping the primary process. However, a review of the limited published data on measured emissions from LHR diesel shows that while there are instance where HC did decrease, there are others where it increased [3]. The most important factors in determining the NO*x* emissions produced by the combustion process are stoichiometry and flame temperature. If combustion took place at the overall lean stoichiometry in the engine cylinder, the NO*x* problem might be relieved, but it does not. Because of the diffusive mixing of fuel and air occurring along the spray envelope, combustion is dominated by near-stoichiometric burning, where production of nitric oxide is high [3].

II. EFFECT OF EXHAUST GAS RECIRCULATION (EGR) ON PERFORMANANCE AND EMISSION CHARACTERISTICS OF THREE CYLINDER DIRECT INJECTION COMPRESSION IGNITION ENGINE

EGR is a very useful technique for reducing the NOx emission. In this research, experimental investigations were conducted to study the effect of EGR on performance and emissions of a diesel engine. EGR displaces oxygen in the intake air by exhaust gas re-circulated to the combustion chamber. Exhaust gases lower the oxygen concentration in combustion chamber and increase the specific heat of the intake air mixture, which results in lower flame temperatures. Reduced oxygen and lower flame temperatures affect performance and emissions of diesel engine in different ways. Thermal efficiency is slightly increased and BSFC is decreased at lower loads with EGR compared to without EGR. But at higher loads, thermal efficiency and BSFC are almost similar with EGR than with-out EGR. Exhaust gas temperature is decreased with EGR, but NOx emission decreases significantly. It can be observed 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. At lower loads, EGR reduces NOx without deteriorating performance and emissions. At higher loads, increased rate of EGR reduces NOx to a great extent but deteriorates performance and emissions. Thus, it can be concluded that higher rate of EGR can be applied at lower loads. EGR can be applied to diesel engine without sacrificing its efficiency and fuel economy and NOx reduction can thus be achieved. The increase in CO, HC, and PM emissions can be reduced by using exhaust after-treatment techniques, such as diesel oxidation catalysts (DOCs) and soot traps (7).

III. EFFECT OF EXHAUST GAS RECIRCULATION IN NOX CONTROL FOR COMPRESSION IGNITION AND HOMOGENEOUS CHARGE COMPRESSION IGNITION ENGINES

In that paper they studied the effect of EGR on NOx emissions and in Compression Ignition (CI) engines at various conditions. To this end, low dimensional models are developed using a first principles approach without recourse to empirics. Fuel oxidation represented by a three-step global kinetic model coupled with the Zeldovich mechanism for NOx formation is used to predict the composition of the entire spectrum of engine-out gases. Solution of the conservation equations using MATLAB provides the in-cylinder variation of parameters like volume, pressure, torque, speed and work done and species (Fuel, CO, CO2, NOX, etc.) with respect to Crank Angle Displacement (CAD). The inlet conditions are the fuel-air equivalence ratio, engine specifications and the inlet air temperature. The simulations are validated against experimental pressure profiles from the literature. External EGR is then implemented to study its effect on engine-out emissions under cold start conditions. The effect of EGR at various combinations of engine operating conditions is examined in detail. [8]

IV. EFFECT OF EXHAUST GAS RECIRCULATION ON DIESEL ENGINE NITROGEN OXIDE REDUCTION OPERATING WITH JOJOBA METHYL ESTER

The interest in renewable energy sources for energy production is not new. Many studies have been conducted to qualify various oil and their blends from plants and vegetables as alternative renewable energy sources. This renewable source of fuel may also help in reducing the net production of CO2 from combustion sources and our dependence on fossil fuels. Often the vegetable oils investigated for their suitability as biodiesel are those which occur abundantly in the country of testing. Jojoba methyl ester (JME) has been used as a renewable fuel in numerous studies evaluating its potential use in diesel engines. These studies showed that this fuel is good gas oil substitute but an increase in the nitrogenous oxides emissions was observed at all operating conditions. The aim of this study mainly was to quantify the efficiency of exhaust gas recirculation (EGR) when using JME fuel in a fully instrumented, two-cylinder, naturally aspirated, four-stroke direct injection diesel engine. The tests were carried out in three sections. Firstly, the measured performance and exhaust emissions of the diesel engine operating with diesel fuel and JME at various speeds under full load are determined and compared. Secondly, tests were performed at constant speed with two loads to investigate the EGR effect on engine performance and exhaust emissions including nitrogenous oxides (NOx), carbon monoxide (CO), unburned hydrocarbons (HC) and exhaust gas temperatures. Thirdly, the effect of cooled EGR with high ratio at full load on engine performance and emissions was examined. The results showed that EGR is an effective technique for reducing NOx emissions with JME fuel especially in light-duty diesel engines. With the application of the EGR method, the CO and HC concentration in the engine-out emissions increased. For all operating conditions, a better trade-off between HC, CO and NOx emissions can be attained within a limited EGR rate of 5–15% with very little economy penalty.[9]

V. EFFECTS OF N-BUTANOL, 2-BUTANOL, AND METHYL OCTYNOATE ADDITION TO DIESEL FUEL ON COMBUSTION AND EMISSIONS OVER A WIDE RANGE OF EXHAUST GAS RECIRCULATION (EGR) RATES.

Haifeng Liu et.al concluded that In order to investigate the effects of fuel properties and oxygenated structures on combustion and emissions, five different fuels n-heptane, iso-octane, n-butanol, 2-butanol and methyl octynoate were added into diesel fuel with the same blending ratio (20% v/ v). A detailed comparative study was conducted on a common-rail heavy-duty diesel engine over a wide range of EGR rates from 0% to 62% to cover both the conventional combustion and the low temperature combustion modes. The main conclusions are as follows:

1. There is little difference in combustion between n-heptane20 and the diesel fuel over a wide range of EGR rates. The ignition delay of iso-octane20 is prolonged compared to n-heptane20 and the effect of cetane number on ignition delay becomes more prominent at higher EGR rates. The combustion characteristics of n-butanol20 are similar to those of iso-octane20.
2. The oxygen in n-butanol20 is the main factor for soot reduction in comparison with diesel fuel. The secondary reason is the longer ignition delay caused by the lower cetane number. Other changes in physical and chemical properties of n-butanol20have quite small effect on soot emission.
3. Compared to methyloctynoate20, additional 12.6% reduction in total soot emissions can be achieved by fueling n-butanol20 + EHN, which is attributed to the different oxygenated structures between n-butanol and methyl octynoate. The locations of OH radical between n-butanol and 2-butanol have very small effect on combustion and soot emissions at 20% blending ratio.
4. The effects of fuel properties and oxygenated structures on soot-reduction efficiencies vary as the EGR rate changes. The soot-reduction efficiency caused by longer ignition delay and oxygen content of the fuels is lowered in the region where the soot emissions increase rapidly as the EGR rates increase. [10]

VI. EXHAUST GAS RECIRCULATION FOR ADVANCED DIESEL COMBUSTION CYCLES.

Usman Asad and Ming Zheng explained the impact of EGR on the intake and in-cylinder charge compositions was analyzed for both transient and steady-state engine operation. One-step global equations to estimate the cycle-by-cycle and steady-state concentrations were proposed and validated in-cylinder excess-air ratio to account for the recycled oxygen with EGR and was shown to be a function of the EGR displacement ratio. The effects of intake pressure and engine load on the quality of EGR were analyzed and it was shown that the intake oxygen concentration provides a reliable measure of the intake charge dilution with EGR, i.e. the EGR effectiveness, compared to the EGR ratio/ fraction. The use of EGR ratio/fraction necessitates the inclusion of additional information about the engine load and intake pressure and is therefore, not a uniform representation of EGR effectiveness. At low loads and low EGR ratios, the effectiveness of EGR in terms of intake dilution is less because the recycled engine exhaust contains significant amounts of oxygen/nitrogen and therefore, displaces a small amount of fresh air in the intake. A higher engine load increases the effectiveness of EGR due to higher intake dilution. Increasing the intake pressure reduces the intake charge dilution for the same EGR ratio. Increasing EGR to revert to the original intake dilution results in a leaner air/fuel ratio with increased, premixed combustion that may provide additional benefits of reduced soot emissions and improved combustion efficiency. [11]

VII. EXPERIMENTAL STUDY ON THE EFFECTS OF HIGH/LOW PRESSURE EGR PROPORTION IN A PASSENGER CAR DIESEL ENGINE.

Youngsoo Park and Choongsik Bae explained in their theory, Diesel engines have been widely adopted for power sources of passenger cars due to their high thermal efficiency. However, the emission regulations, which are becoming increasingly stricter, are forcing manufacturers to produce cleaner diesel engines. Car manufacturers are now in a situation whereby they need to reduce the nitrogen oxides (NOx) level by more than half of the present level in order to fulfill the EURO-6 regulations while maintaining the current particulate matter (PM) level. PM emission could be reduced by equipping a technologically matured diesel particulate filter (DPF) with a filtration efficiency of more than 90% [1]. After treatment systems for reducing NOx such as a lean NOx trap (LNT), a urea selective catalytic reduction (SCR), and other de NOx catalysts are now available; however, these show a spatial constraint when applied to passenger cars [2,3]. They conducted experimental study to investigate the effects of the proportion between high pressure and low pressure exhaust gas recirculation (HP/LP EGR) on engine operation. Their study focused on the characteristics of combustion, emissions, and fuel consumption in a 2.2 L passenger car diesel engine. The experiments were performed under three part-load and steady-state operating conditions. The LP EGR portion was swept from 0 to 1, while the mass flow rate of fresh air and boost pressure were fixed. The results showed that the intake manifold temperature decreased gradually as the LP EGR portion increased due to its greater cooling capability by a longer supply line and an intercooler. However, the required cooling power for the intercooler increased because the LP EGR gas, which has a higher temperature than the fresh air, was induced upstream of the compressor. The lowered intake manifold temperature with the increase of the LP EGR portion led to the prolonged ignition delay of pilot injections, which resulted in a slightly higher peak heat release rate in the main combustion. A higher LP EGR portion showed a lower fuel consumption level than the HP EGR only case because the variable geometry turbocharger (VGT) nozzle opened more widely to maintain the boost pressure, which means a lower pumping loss. Nitrogen oxide (NOx) emissions were also decreased as the LP EGR portion increased due to lowered intake charge temperature. Consequently, it was possible to improve the trade-off relationship between NOx emissions and fuel consumption with the increase of the LP EGR portion under steady-state operating conditions. [12]

VII. EXPERIMENTAL STUDY OF NO*X* EMISSIONS AND INJECTION TIMING OF A LOW HEAT REJECTION DIESEL ENGINE.

Ekrem Buyukkaya and Muhammet Ceritdone an experimental study of the effects of injection timing on nitrogen oxide (NO*x*) emissions of a low heat rejection (LHR) turbocharged direct injection diesel engine. The injection timing and brake specific fuel consumption (BSFC) trade-off must be considered together in performance and NO*x* emissions analysis. For the original injection timing of the 20◦ before top dead centre, the brake specific fuel consumption value of the LHR engine was approximately 6% lower than the original engine. NO*x* emissions were also higher (about 9%) than the original engine. To reduce NO*x* emissions released by diesel engines, the method of injection timing retard was utilized. Thus, the LHR engine was tested for two different injection timings; 18◦ and 16◦ crank angle before top dead centre (BTDC), at the same engine speeds and load conditions. The results showed that the BSFC and NO*x* emissions were reduced 2% and 11%, respectively by retarding the injection timing. Optimum injection timing for the LHR engine was obtained through decreasing by 2◦ BTDC. [13]

VIII. CONCLUSDION

From above literature survey it is concluded that if the 5% to 15% cooled exhaust gas recirculated to engine then the efficiency of NO_x reduction will get maximum. Fuel properties and oxygenated structures have little effects on NOx, CO, THC emissions and gross indicated thermal efficiency. However, the changes in EGR rates have dominant effects on the gaseous emissions and indicated thermal efficiency. The use of EGR cooler at full load has a positive effect on improving the engine economy and decreasing the exhaust emissions.

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