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A Critical Review of Exhaust Recirculation Gas System for CI Diesel Engine

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Abstract:

The steep rises in the prices of the petroleum fuels and the concern for the environment have forced the researchers to find alternative renewable fuels which are called bio-fuels. It is possible to limit the negative effect of NOx on the environment by various methods like exhaust gas recirculation (EGR), catalyst and water injection. nitrogen oxides (NOx) contribute to a wide range of environmental effects including the formation of acid rain and destroy ozone layer. In-cylinder high temperature flame and high oxygen concentration are the parameters which affect the NOx emissions. The EGR system was a very effective way for reducing NOx emission from a diesel engine , particularly at the high load of engine operation condition. A review have been made for exhaust recirculation gas system attempted by others in the past.

Keywords: exhaust gas, diesel engine, emissions etc.

I. INTRODUCTION AND REVIEW

M. Anandan,[1] presented in their technical paper deals with combustion, emission and performance characteristics of a single cylinder DI diesel engine for biodiesel blends (J10, J20, J30, P10, P20,P30) with the optimum use of EGR system by the formulation of matrix analysis. Compressionratios like 17.5:1, 19:1, 20:1 were varied. The piston was modified by cold metal transfer (CMT) welding with the use of aluminium alloy on the piston bowl of the diesel engine. Tests were performed at different loading conditions and results were obtained. The performance studysuggests that BTE was found to be increased with J20 CR20 and slight reduction withcu J20 CR20E20 blend compared to diesel. Peak pressure was higher for J20 CR20 conforming better combustion characteristics over other biodiesel blends. Ignition delay were shorter for J20 CR20and P20 CR20 blends with crank angle varying from 23.4 deg to 10.78 deg for J20 CR20 and23.4 deg to 10.48 deg for P20 CR20 before TDC. NOx emission was increased with the increasein percentage of biodiesel blends. Significant NOx reduction in biodiesel blends were found withthe use of EGR in J20 CR20 EGR20 and P20 CR20 EGR20.

Aparna V. Kulkarni [2] presented in their technical paper to reduce NOx emission by using an effective after gas treatment technique like cooled Exhaust Gas Recirculation (EGR) as it enables lower flame temperature and oxygen concentration in combustion chamber. In the present work, experiments are conducted on 5.2 KW(7 HP) single cylinder,four stroke, water cooled, direct injection, naturally aspirated diesel engine fitted with short loop, cooled EGR system.Diesel, biodiesel and their blends were used as fuel for conducting experiments. Based on this study, it can be concluded that BD20 CSOME with 12% cooled EGR rate produced 27% less NOx emission without any significant engine performance-emission penalties. Hence it is recommended to use BD 20 CSOME as substitute fuel with 12% cooled EGR rate for optimum performance-emission characteristics

Kavati Venkateswarlu, et al [3] presented in their technical paper the combined effect of EGR and cetane improver can effectively reduce the Nitrogen Oxides (NOx) emissions by reducing the combustion temperatures, since NOx formation is a temperature dependent phenomenon in diesel engines. In the present work, experimental investigations were carried out on a single cylinder four stroke naturally aspirated direct injection air cooled diesel engine with exhaust gas recirculation and cetane improver Di Tertiary Butyl Peroxide (DTBP) as an additive to diesel-biodiesel blends. The combined effect of EGR and DTBP on Brake Thermal Efficiency(BTE), Brake Specific Fuel Consumption (BSFC), cylinder pressure and exhaust emissions is studied. From experimental results it is found that an EGR percentage of around 15% results in maximum BTE and minimum BSFC. It is also found that the combined effect of EGR and cetane improver reduces the NOx emissions by 25% with a slight increase in Carbon Monoxide (CO), Hydro Carbon (HC) and smoke opacity.

Pooja Ghodasara, M.S. Rathore [4] presented in their technical paper the usage of biodiesel and EGR simultaneously in order to reduce the emissions of all regulated pollutants from diesel engine. For this a single cylinder, air cooled, constant speed direct injection diesel engine was used and EGR was developed and fitted in engine. Various emissions such as HC, NOx, CO and smoke opacity were measured. The engine performance parameters were calculated from measured data.

Vipul Jain, [5] presented in their technical paper exhaust Gas Recirculation (EGR) System means to use the Exhaust Gas coming from Exhaust Manifold to Inlet Manifold in order to reduce the Emission of NOX, which is particularly very harmful. Engine without EGR are more pollutant & uses more atmospherically air for combustion. By Implementation of EGR system in Engine, the Partial Exhaust Gas is re-circulated again in Engine. It is first cooled in EGR Cooler & then it

is mixed with atmospheric air & then passed to Combustion Chamber. Fresh atmospheric air required was reduced & automatically pollutant (CO, CO2, HC, NOX etc.) is reduced. The aim of this work is to review the potential of exhaust gas recirculation (EGR) to reduce the exhaust emissions, particularly NOX emissions, and to delimit the application range of this technique. The purpose of project is to plot the graph between Brake power (B.P.) Vs. NOX, B.P. Vs. CO2, B.P. Vs CO with & without implementation of EGR. The Major Task of the proposed work includes Calculation of NOX content in I.C. Engine with or without the Implementation of EGR System. The system is very much Eco Friendly. Using Exhaust Gas Recirculation (EGR) Technique in engines, the emissions are very much controlled. This method is very reliable in terms of fuel consumption.

B. Jothithirumal & E. James Gunasekaran[6] presented in their technical paper the optimum EGR and biodiesel blend matrix for the better performance and optimum emission reduction in a DI diesel engine. The bio fuel used in the experimentation is derived from the Neem oil. A twin-cylinder, aircooled,constant speed direct injection diesel engine is used for experiments. HC, NOx, CO, and smoke of theexhaust gas are measured. Various engine performance parameters such as thermal efficiency, and brakespecific fuel consumption are calculated from the acquired data. As the percentage of bio diesel increased indiesel and bio fuel blend the NOx emission increased. In order to reduce the emission from bio diesel EGR isused. Application of EGR with biodiesel blends resulted in reductions in NOx emissions without any significantpenalty in smoke emissions. The results reveal that the Blend 100 (100 % bio fuel) produces maximum NOxemission (300 ppm). With 25% volume flow rate of EGR with the same B100 bio diesel, the NOx emission is reduced approximately 300 ppm to 100 ppm Harilal S. Sorathia[7] presented in their technical paper internal combustion engines are established as the main power source for the automobile vehicles. At present emission norms becomes strict for any I.C. Engine. The main pollutant are CO, HC, NOx, PM, soot, etc from which NOx are one of the most harmful component. 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 common 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 beneficial to reduce the NOx emission substantially. Substantial reductions in NOx emission are achieved by previous 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, decrease of peak cylinder temperature and decrease in O2 concentration in cylinder charge and decrease the air-fuel ratio.

A. Mohebbi et al[8] presented in their technical paper nitrogen oxides influence of EGR on diesel engine combustion, NOx/PM emissions, brake specific fuel consumption (BSFC), engine thermalefficiency, cylinder pressure and heat release rate (HRR) are analyzed and presented. The experiments have beenconducted on a turbocharged DI diesel engine under full load condition at two different injection timings in order todistinguish and quantify some effects of Hot and Cooled EGR with various rates on the engine parameters.Experimental results showed that increase of EGR rate has a negative effect on air-fuel ratio. For a premixedcombustion at constant boost pressure, ignition delay is increased leading to retardation of all combustion process, alow HRR peak and reduce of in-cylinder peak temperature. Using of Hot EGR reduces NOX emissions whereas PMemissions are increased. The advance of injection timing resulted in the reduction PM while both NOX emissions andfuel consumption were increased. The use of cooled EGR was more effective compared to the hot EGR. As a result,the EGR temperature has no significant impact on NOx emissions. With increasing EGR rate, unequal EGRdistribution was increased in inlet port of cylinders while the reducing EGR temperature (cooled EGR) improved itsdistribution among the engine cylinders and decreased the EGR cylinder-to-cylinder variations.

B Lakshmana Swamy et al [9] presented in their technical paper the cooling rate of an IC engine stands one of important parameters that govern the performance and emissions. In our present experimental investigation emissions of a Kirloskar AV-1 single cylinder, water cooled, diesel engine was observed at various cooling rates and compared with that of operated under Exhaust Gas recirculation(EGR). Experiment was conducted in various cycles by varying loads, cooling rates and recirculation of exhaust gas. Exhaust Gas recirculation was done by provision in the test rig that is provided with a valve for managing flow and a U-tube manometer for measurement of the EGR flow. The EGR proportion of 18% was maintained as this proportion of EGR substitution was the maximum that did not detoriate the performance of engine further substitution had led to slow down of engine. The emissions NOx in PPM, CO in %vol, CO2 %vol, HC in PPM & un reacted O2 in %vol was measured using MN-05 multi gas analyzer.

A. Raj Kumar et al[10] presented in their technical paper exhaust Gas Recirculation (EGR) System means to use the Exhaust Gas coming from ExhaustManifold to inlet manifold in order to reduce the emission ofNOX, which is particularly very harmful. Engine withoutEGR are more pollutant and uses more atmospheric air forcombustion. By implementation of EGR system in engine, thepartial exhaust gas was re-circulated again in engine. It was firstcooled in EGR Cooler & then it was mixed with atmosphericair & then passed to Combustion Chamber. Fresh atmospheric air required is reduced & automaticallypollutant (CO, CO2, HC, NOX etc.) was reduced. In the present work was to review the potential of exhaust gas recirculation(EGR) to reduce the exhaust emissions, particularly NOXemissions, and to delimit the application range of this technique with different.

Isobutonal blends with diesel. In the present investigation brake mean effective pressure was highest at 5% of Isobutonal with 17.9225 of EGR and the brake thermal efficiency 22.65%. The system was very much Eco Friendly. Using ExhaustGas Recirculation (EGR) Technique in engines, the emissions are very much controlled. This method is very reliable in terms of fuel consumption

P. Suresh Kumar et al [11] presented in their technical paper have proposed various solutions towards reducing pollutant emissions, especially nitrogen oxides (NOX), from indirect injection diesel engines. The aim of the present

work is to investigate the influence of exhaust gas recirculation (EGR) rates on Jatropha biodiesel (JB), diesel and their blends. A indirectinjection (IDI) diesel engine was tested by diesel,100% biodiesel (JB100), blends of 20% diesel and 80%biodiesel (JB80) ,and other blends like JB60, JB40,and JB20. The engine characteristics with Jatrophabiodiesel were compared against those obtained using diesel fuel. From the results, it was observed that thebiodiesel performance and emission are lower than that of diesel fuel. However, the NOx emission of Jatropha biodiesel was more than that of diesel fuel. The EGR system reduces NOX emissions by recirculation smallamount of exhaust gases into the intake manifold. The main focus of this dissertation was on finding out the bestor the most suitable blend of biodiesel which when used gives out least automotive NOx emissions using a EGRsysrem. A single cylinder water cooled IDI diesel engine was used for investigation. Smoke , NOx ,CO, CO2emissions were recorded and various engine performance parameters were also evaluated . The results anddiscussion based on the effect EGR system on engine performance and emission characteristics of JB20, JB40,JB60, JB80, JB100 and diesel fuel without EGR rates and with EGR rates. The performance parameters andNOx emissions are measured and recorded for diesel fuel and JB and their blends. The results showed that, at15% EGR diesel, JB 20 at 25% EGR, JB 40 at 15% EGR, JB 60 at 20% EGR, JB 80 at40% EGR, and JB 100at 5% EGR, the NOx emissions are effectively reduced by 10.1%,11.94%,13.4%,15.2%,19.85%, and 24.8% respectively.

Pooja Ghodasara, Mayur Ghodasara [12] presented in their technical paper human consumption of energy in the form of fossil fuels has been a matter of great concern. There is a need to increase energy supplies to meet basic needs and to do it in a way that promotes sustainable development. Bio-diesel is an attractive alternative fuel which is renewable, non-toxic, reduces carbon monoxide and hydrocarbon emission due to higher content of oxygen. Bio-diesel has higher kinematic viscosity, low calorific value, poor fuel atomization, piston ring sticking and has lubricating oil dilution problem but this fuel is can be used as blend with diesel to overcome all these problems. Biodiesel blends has sort out many problems like reducing carbon dioxide, carbon monoxide and hydrocarbon emissions. Along with this biodiesel has high cetane number which is a measure of fuel's ignition quality. It replaces the exhaust odour of petroleum diesel with more pleasant smell of popcorn or French fries. Though many advantages biodiesel is not so popular because of high NOx emission. So to take advantage of this alternative fuel one EGR technique has been developed to reduce NOx emission as it enables lower flame temperature and oxygen concentration in combustion chamber. The objective of this study is to investigate the usage of biodiesel blends and EGR simultaneous in order to reduce NOx emission along with other regulated pollutants from diesel engine without any engine modification. For this single cylinder, naturally aspirated air cooled direct injection diesel engine is used for experimental work and different blends of biodiesel like B-20, B-50 and B-100 are used to compare the engine performance and parameters such as brake thermal efficiency, exhaust gas temperature and emission characteristics are calculated from measured data.

Ambarish Datta [13] presented in their technical paper environmental degradation and depletion of fossil fuel reserves are matters of great concern around the world. Diesel is one of the main transport fuel used in sector and India depends heavily on oil import. Recent concerns over the environment, increasing fuel prices and shortage of its supply have promoted the interest in development of the alternative sources for petroleum fuels. It is observed by several researchers that with biodiesel fuelled compression ignition (CI) engine; the exhaust emission is lower than that of diesel, whereas the NOx emission increases due to the excess oxygen content and high in-cylinder temperature of biodiesel. So, the exhaust gas recirculation (EGR) technique may be employed to lower the NOx emissions form CI engines. Although, EGR in CI engine has a number of benefits on the combustion process and emissions, its effect on the performance of the engine should be critically evaluated. Keeping this in mind, only the performance characteristics of a double cylinder, water cooled, four stroke, direct injection compression ignition engine fuelled with jatropha biodiesel-diesel blends (10%, 15%, 20%, 25%, 30% and 50%) have been investigated and compared to mineral diesel with 15% exhaust gas recirculation. The lower blends of biodiesel increases the thermal efficiency and reduces the fuel consumption. Exhaust gas recirculation improves brake thermal efficiency and fuel consumption.

G.Naresh Babu et al [14] presented in their technical paper as day by day there is technological development seen all around world, the research work is progressing but the resources involved in them are depleting rapidly .The demand of resources andfuels for the technological development is increasing day by day. In order to keep the pace ofdevelopment high there is a need to think about some alternate fuel with better efficiency which wouldhelp overcome the demand keeping in mind the resources for the future generation. An alternate fuelneeds to be developed and researched upon which could help us get greener and better tomorrow. Oneof the reasons for this is emission of exhaust gases like NOX, CO, HC, etc., from I.C Engines. The amountof NOx formed is lesser when the blends of biodiesel are used. But Exhaust Gas Recirculation (EGR) forbiodiesel blends the formation of NOx is comparatively reduced and also thermodynamic efficiency ofthe engine is increased. This work highlights upon the usage of Pine oil as alternative fuel for acompression ignition engine and study the performance and emission characteristics of this fuel withExhaust Gas Recirculation system at different quantities of EGR rates with different loads.

Shaik Khader Basha et al [15] presented in their technical paper the effects of hot and cold Exhaust gas recirculation (EGR) methods on emissions and efficiency of the single cylinder, 4-stroke, direct injection diesel engine. For getting different EGR methods heat exchanger is provided. With and without Exhaust gas recirculation the performance characteristics like efficiencies, emissions were studied. In this project the different amounts of EGR like 10%, 15% and 20% of EGR is used to study the effects on the performance characteristics The recirculation of exhaust gas reduces the oxygen quantity in the combustion chamber and increases the temperature of intake charge which reduces the flame temperature and makes to lower NOx formation. By increasing the cooled EGR rates reduces the emissions more effectively.

Vijayakumar et al [16] presented in their technical paper transtesterified fuels (biodiesel) from vegetable oils are alternative fuels for diesel engines. However several studies reported that diesel engine fueled with bio-diesel emits more NOx emissions. To meet diesel vehicular exhaust emission norms worldwide, several exhaust pretreatment and post treatment technique have been employed in diesel engine. This project aims at experimental investigation on effect of EGR in performance and emission characteristics of a diesel engine fueled with biodiesel. The performance and emission parameters were studied with different EGR valve opening 5%, 10% and 15% respectively. The results shows that, engine emits NOx when fueled with bio-diesel (without EGR). It is due to long hydrocarbon chain and lack of oxygen content. With increase in EGR flow rates; there will be reduction in NOx was observed. But hydrocarbon emission, CO, CO2 were increased slightly at high loads. Whereas there is no major variation in brake thermal efficiency was observed.

Dhaneshkumar A [17] presented in their technical paper multi-fold growth in vehicular population. As a result there is a marked decrease in ambient air quality because of the pollutants released by these vehicles both on and off road. It also leads torise in Green House Gas emission because of more CO2 released to the environment. Hence researchers focus on fuelconsumption and emission reduction. Due to depleting fossil fuel reserves, there is growing demand to switch over toalternative fuels. Alternative fuels like biodiesel and ethanol are renewable and relatively green, being derived fromvegetable oil and sugar molasses respectively. Recently, blending of fuels to improve the combustion properties of fuelis being employed as an option.

D'Errico, G. et al [18] presented in their technical paper multiple injections and high EGR rates are now widely adopted for combustion and emissions control in passenger car diesel engines. In a wide range of operating conditions, fuel is provided through one to five separated injection events, and recirculated gas fractions between 0 to 30% are used. Within this context, fast and reliable multi-dimensional models are necessary to define suitable injection strategies for different operating points and reduce both the costs and time required for engine design and development. In this work, the authors have applied a modified version of the characteristic time-scale combustion model (CTC) to predict combustion and pollutant emissions in diesel engines using advanced injection strategies. The Shell auto-ignition model is used to predict auto-ignition, with a suitable set of coefficients that were tuned for diesel fuel. The standard CTC model was improved by introducing a new expression to compute the characteristic time-scale together with multiple time-scales that were considered to estimate the reaction rates of the chemical species. Soot emissions were predicted by the eight reaction step mechanism proposed by Fusco and the extended Zeldovich mechanism was used to estimate NO_x concentration. The proposed combustion model has been implemented into the Lib-ICE code, which is a set of libraries and applications for IC engine modeling developed under the OpenFOAM® technology. The spray is described by using the conventional Eulerian-Lagrangian approach and the Huh-Gosman model is used to describe the primary atomization of the liquid jet. To validate the proposed approach in a wide range of operating conditions, a suitable methodology was developed to define a suitable case setup for any of them in terms of initial conditions and spray model constants. Experiments conducted in a common-rail, turbocharged diesel engine were used for experimental validation, and a detailed comparison will be provided between measured and computed data of in-cylinder pressure, heat release rate and pollutant emissions.

Park, W. et al [19] presented in their technical paper the EGR stratification concept was improved with a CFD-based analysis. First, a two-step piston was developed to maximize the stratified EGR effect. Then, the feasibility of combustion and emission control by stratified EGR was evaluated under cases of artificially distributed EGR stratification and conventional diesel engine conditions

III. CONCLUSIONS

1. Experimental results shows that the cold EGR is much effective than the hot and intermediate EGR for the reduction of NOx emission. The increase in temperature of EGR gases causes to increase the combustion temperature which leads to increase in formation of NOx.
2. The Volumetric efficiency was almost same in all the cases and the brake specific fuel consumption was lower at 7% of Isobutonal with 22.65% of EGR

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