PERFORMANCE OF DIESEL ENGINE WITH EGR SYSTEM

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ABSTRACT
Reducing NOx emission in a diesel engine is a major issue for its environmentally harmful influences. To cope with the problem, the current diesel engine is equipped with EGR. Actually, it is known that EGR can help to reduce NOx emission by limiting oxygen supplied into intake manifold, lowering the combustion temperature. However, it also reduces engine performance. In the present investigation is carried out to study the effect of the Exhaust Gas Recirculation (EGR) on the performance and emission characteristics of the C.I. engines. To overcome the problem of NOx formation in the CI engine due to higher temperature the part of exhaust gases are recirculated to the engine cylinder. The EGR rate is varied in the engine I the proportion from 0%, 5%, 10 % and 15%. One set of experiment is conducted for each EGR rate, for studying the performance & emission characteristics of the engine. Then the performances and emissions characteristic for EGR rates were studied and results were compared with the performance and emission characteristics of without EGR.

KEYWORDS: NOx emission, Exhaust Gas Recirculation (EGR), diesel engine performance

INTRODUCTION

The EGR system is designed to reduce the amount of oxides of nitrogen (NOX) created by the engine during operating periods that usually results in high combustion temperatures, NOx is formed in high concentrations whenever combustion temperature exceed about 25000 F. In this recirculation system a portion of an engine's exhaust gases are recirculated back into the engine cylinders. In diesel engines exhaust gas replaces some of the excess oxygen in the combustion chamber. The EGR system reduces NOx production by recirculation small amount of exhaust gases into the intake manifold where it mixes with the incoming air. By diluting the air mixture under these conditions, peak combustion temperature and pressure are reduced, resulting in an overall reduction of NOx output. The aim of the present research study is to investigate the effect
of EGR on emissions and performance parameters of an indirect injection diesel engine (IDI) fuelled with diesel. The current study has been undertaken in order to evaluate the performance of the diesel engine with the varying EGR rates and its effect on the emission characteristics of the engine with special attention on the NOx emission from the diesel engine.
The problem statements of this experiment are shown below:
1. The advantages of using EGR in solving the problem to reduce the amount of nitrogen oxide in exhaust gas emission and
2. To study the effect of EGR on the performance and emissions characteristics of the diesel engine and without EGR system.

METHODOLOGY AND EXPERIMENTATION

One of the primary motivations of this project was the difference between the results from similar previous work and experimental results from the experiments for high levels of EGR.

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2.1 DESCRIPTION OF EXPERIMENTAL TEST SET UP

The experimental test setup consists of a, compression ignition engine, with eddy current dynamometer as loading system, fuel supply system, water cooling system, exhaust gas recirculation system, lubrication system and various sensors and instruments. Figure 3.1 is the photographic image of the experimental setup used in the laboratory to conduct the present study and figure 3.2 and 3.3 represents the schematic representation of the experimental test setup. Table 3.1 gives the specifications of engine used in the test rig. The setup enables the evaluation of thermal performance and emission constituents of the VCR engine. The thermal performance parameters include brake thermal efficiency, brake specific fuel consumption, and exhaust gas temperature. The exhaust emissions of the engine are analyzed using an exhaust gas analyzer. The constituents of the exhaust gas measured are CO (%), CO_2 (%), HC (ppm), NOx (ppm).

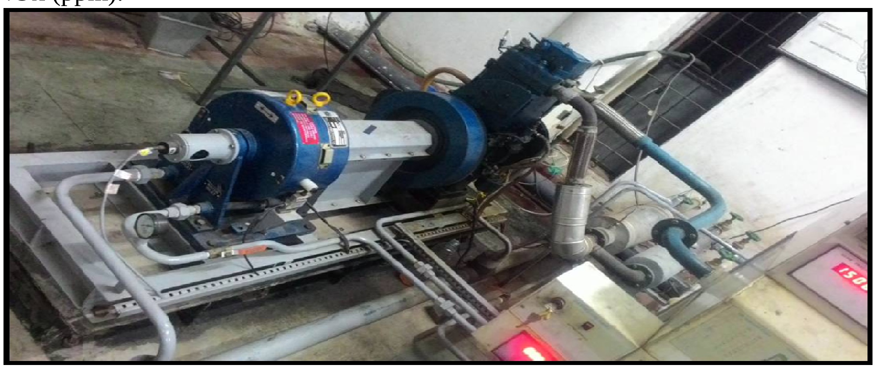

Figure 2.1.1 Test set up

2.2 MEASUREMENT SYSTEMS

Various measurement systems used to capture the experimental data used in the test rig are load measurement system, emission measurement system and data acquisition system.

2.2.1. LOAD MEASUREMENT SYSTEM

The experimental study is conducted at various loads and hence an accurate and reliable load measuring system is a must. The load measuring system of this experimental test rig consists of a dynamometer of eddy current type, a load cell of strain gauge type and a loading unit. The load is applied by supplying current to the dynamometer using a loading unit. The load applied to the engine is measured by a load cell. The dynamometer, load cell and loading unit are discussed in the following paragraphs.

A dynamometer is a device which is used for measuring force, torque or power produced by an engine. It can also be used to apply load or torque on the engine. The dynamometer used in this study is an eddy current type with a water cooling system. The eddy current dynamometers provide an advantage of quicker rate of load change for rapid load setting. The VCR diesel engine is directly coupled to the eddy current dynamometer with a loading unit using which desired loads up to 12 kg can be applied. The load measurement is made using a strain gauge load cell and the speed measurement is done using a shaft mounted on a crank angle sensor. The eddy current dynamometer unit basically comprises of a rotor, shaft, bearings, casing and bed plate. The rotor is mounted on the shaft which runs in the bearings. The bearings rotate within the casing supported in ball bearing which form a part of the bed plate of the machine. Inside the casing, there are two field coils connected in series. When a direct current is supplied to these coils using a loading unit, a magnetic field is created in the casing across the air gap on either side of the rotor.

2.2.2 EMISSION MEASUREMENT SYSTEM

The emission measurement system is used to measure the constituents of exhaust gas and for this AIRREX Automotive Emission Analyzer is used. The exhaust gas analyzer measures the exhaust gas constituents of carbon dioxide (CO_2), carbon monoxide (CO), oxides of nitrogen (NOx), unburnt hydrocarbons (HC), and oxygen (O_2). A photographic image of the assembly of the emission measurement systems used in the experiment is given in figure2.2.2

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Fig. 2.2.1 Exhaust gas analyzer

EGR TECHNIQUE FOR NOX REDUCTION

EGR is a useful technique for reducing NOx formation in the combustion chamber. Exhaust consists of CO_2, N_2 and water vapors mainly. When a part of this exhaust gas is re-circulated to the cylinder, it acts as diluents to the combusting mixture. This also reduces the O_2 concentration in the combustion chamber. The specific heat of the EGR is much higher than fresh air; hence EGR increases the heat capacity (specific heat) of the intake charge, thus decreasing the temperature rise for the same heat release in the combustion chamber,

EGR %= (Volume of EGR/total intake charge) x 100

Three popular explanations for the effect of EGR on NOx reduction are increased ignition delay, increased heat capacity and dilution of the intake charge with inert gases. The ignition delay hypothesis asserts that because EGR causes an increase in ignition delay, it has the same effect as retarding the injection timing. The heat capacity hypothesis states that the addition of the inert exhaust gas into the intake increases the heat capacity (specific heat) of the non reacting matter present during the combustion. The increased heat capacity has the effect of lowering the peak combustion temperature. According to the dilution theory, the effect of EGR on NOx is caused by increasing amounts of inert gases in the mixture, which reduces the adiabatic flame temperature. Implementation of EGR in diesel engines has problems like (a) increased soot emission, (b) introduction of particulate matter into the engine cylinders. When the engine components come into contact with high velocity soot particulates, particulate abrasion may occur. Sulphuric acid and condensed water in EGR also cause corrosion. Some studies have detected damage on the cylinder walls due to the reduction in the oil's lubrication capacity, which is hampered due to the mixing of soot carried with the particulate laden recirculated exhaust gas. This necessitates the use of an efficient particular trap. Studies have shown that EGR coupled with a high collection-efficiency particulate trap, controls smoke, unburnt hydrocarbon and NOx emissions simultaneously. The particulate trap, however, needs to be regenerated since its pores get clogged by the trapped soot particles. Clogged soot traps increase backpressure to the engine exhaust, thus affecting engine performance also. These traps need to be regenerated from time to time using thermal or aerodynamic or electrostatic regeneration techniques. Other methods of reducing the particulate emission from diesel engines include multiple injections, supercharging and higher fuel injection pressure etc. The highest attention is currently being paid to two self-regenerating systems: fuel additive-supported regeneration by using cerium- or iron-based additives, and a continuous regeneration trap (CRT) using sulphur-free diesel fuel.

EXPERIMENTAL PROCEDURE

The present study was carried out to investigate the performance and emission characteristics of diesel engine at various EGR rates and without EGR, in a stationary single cylinder, four stroke, engine. The eddy current dynamometer is used as a loading device whose power absorption unit consist of a well-balanced star wheel rotor mounted on precision bearings, rotates in the stator. The reaction torque is sensed by using various weighing mechanism such as spring balance or load cell with digital indicator etc. The main shaft of the dynamometer is having arrangement for fitting flange coupling at both ends. The control of extension unit is mounted on a separate panel.

The major pollutants in the exhaust of a diesel engine are CO, CO_2, HC and NOx. Exhaust gas analyzer was used for the measurement emissions. The engine was operated on diesel without EGR first and then on different EGR rates. The performance data were then analyzed from the graphs regarding thermal efficiency, brake-specific fuel consumption and exhaust gas temperature.

The diesel fuel was first tested at zero EGR and at variable loads. Keeping the no EGR condition and varying the load in the range of 3 kg, 6 kg, 9 kg and 12 kg all the performance parameters are noted. The EGR rate was then changed to 5%, 10% and 15% and the performance parameters were recorded for each load considered. The procedure for the various tests is as given below;

For getting the base line data of the engine first the experimentation is performed with diesel without any EGR.

1. Fill the diesel in fuel tank.
2. Initially adjust the EGR rate to zero EGR by keeping EGR valve closed.
3. Start the water supply. Set cooling water flow for engine at 150 LPH and calorimeter flow at 80 LPH.
4. Check for all electrical connections.
5. Also ensure adequate water flow rate for dynamometer cooling and piezo sensor cooling.
6. Supply the diesel to the engine by opening the valve provided at the burette.
7. Repeat the experiment for different load.
8. Note down the readings for particular compression ratio.
9. Change the EGR valve position as per requirement.
10. Repeat the whole experiment for different EGR rates.
11. Note down the readings for each EGR rate.
12. At the end of the experiment bring the engine to no load condition and turn off the engine

RESULTS AND DISCUSIONS

Engine tests were carried out using diesel at 1500rpm and different EGR rates in order to study the effect of EGR on the performance and emission characteristics. Higher amount of smoke in the exhaust is observed when the engine is operated with EGR compared to without EGR. EGR reduces availability of oxygen for combustion of fuel, which results in relatively incomplete combustion and increased formation of PM and reducing NOx emissions from diesel engine.

5.1 BRAKE SPECIFIC FUEL CONSUMPTION (BSFC):

Figure 4.1 shows the variations of BSFC for diesel with and without EGR. The brake specific fuel consumptions are lower for diesel at lower loads operated with EGR when compared to without EGR.

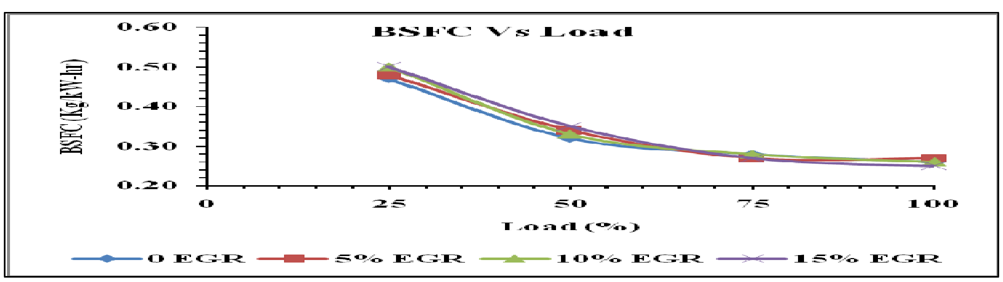

Figure 5.1 .1Variation of brake specific fuel consumption with engine load

However, at higher engine loads, BSFC with EGR is almost similar to that of without EGR for diesel fuel. The 15% EGR rate has shown lower BSFC as compared other EGR rates and without EGR.

5.2 BRAKE THERMAL EFFICIENCY (BTHE):

Figure 5.2.1shows the variations of brake thermal efficiency of diesel engine with EGR and without EGR. The brake thermal efficiencies are increased with increase in load with EGR. At lower load due to re-burning of hydrocarbons

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that enter in to the combustion chamber with the recirculated exhaust gases and at full load operation the brake thermal efficiency not affected by exhaust gases. As shown in figure, when Brake power of the engine increases, the Brake thermal efficiency of the engine is also increases.

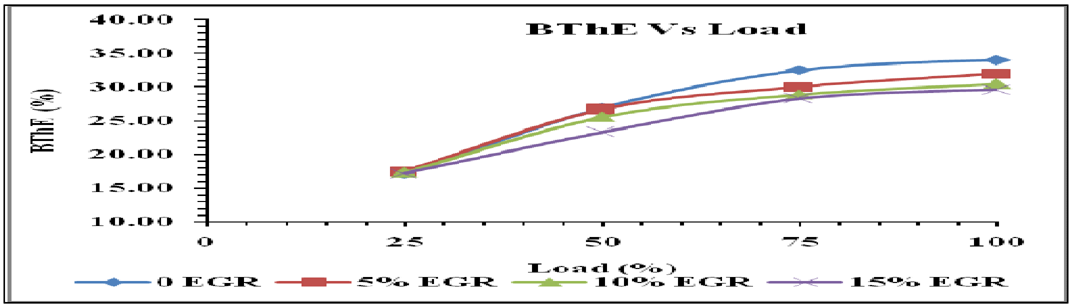

Figure 5.2.1 Variation of brake thermal efficiency with engine load

At higher loads and at EGR rate 15%, thermal efficiency tends to decrease slightly. This may be due to the fact that the amount of fresh oxygen available for combustion gets decreased due to replacement by exhaust gas.

5.3EXHAUST GAS TEMPERATURE (EXGT):

Figure 5.3.1 shows the variations of exhaust gas temperature with EGR and without EGR. It can be observed that with increase in load, exhaust gas temperature also increases. The exhaust gas temperature was found to be lower for EGR-operated engine with diesel due to lower availability of oxygen for combustion and higher specific heat of intake exhaust gas air mixture.

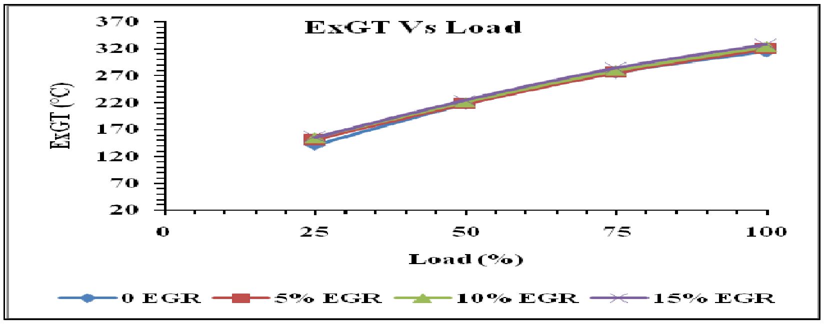

Figure 5.3.1 Variation of exhaust gas temperature with engine load

Our experimental results indicate a decrease in the exhaust temperatures with increasing EGR, therefore it can be safely concluded that the combustion chamber temperatures also decrease and thus the formation of NOx is decreased.

EFFECT OF EGR ON THE EMISSION CHARACTERISTICS OF THE CI ENGINE

It is important to have a thorough understanding of the emissions associated with engine. Understanding the exhaust emissions will help in determining the feasibility of using EGR in the CI engine. The effect of EGR is specific for each type of pollutant and depends on engine type, operating conditions, and the origin and quantity of EGR. Pollutants of interest include, CO, CO_2, UHC and NOx. The overall objective of the results discussed in this section was to gain a better understanding of EGR by determining the relationship between pollutant concentrations in diesel engine exhaust with and without EGR.

During the emissions tests concurrent with performance tests, engine exhaust emission measurements were collected at specific interval during each performance test for each EGR at each load. Exhaust concentrations for UHC and NOx were measured in units of ppm, while CO and CO_2 were measured in percentage. The results obtained from the engine emission are discussed in the following sections.

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6.1 CARBON MONOXIDE (CO)

Carbon Monoxide emissions are the result of the lack of oxygen and low combustion temperature, resulting in incomplete oxidation of CO to CO_2.Hence study of CO emissions is very important.

Figure 6.1.1 shows the variations of CO emissions of diesel and sunflower methyl ester with EGR and without EGR. The CO increases with increase in load and EGR rate. However, CO emissions for diesel were comparatively lower. Higher values of CO were observed at full load for with EGR and without EGR. Dissociation CO_2 to CO at peak loads where high combustion temperatures and comparatively fuel rich operation exists, can also contribute to higher CO emissions. It is observed that from the graph CO emissions are lower for the 0 % EGR and 5 % EGR and higher for the 10% EGR and 15 % EGR rates.

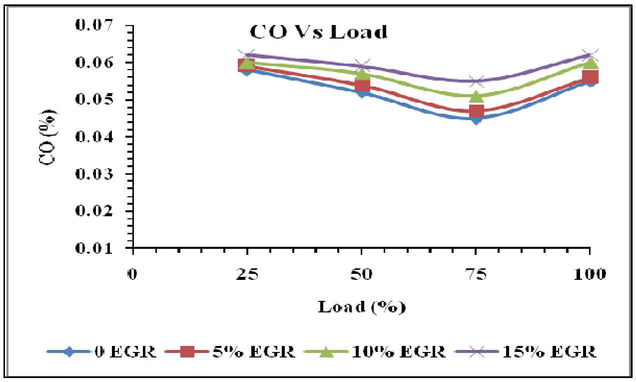

Figure6.1.1 Variation of carbon monoxide with engine load

6.2 HYDROCARBONS (HC)

Figure 6.2.1 shows the variations of HC emissions of engine with and without EGR. The HC decreases with increase in load and EGR rate because of the combustion of the unburned HC form exhaust gases after recirculation in the combustion chamber.

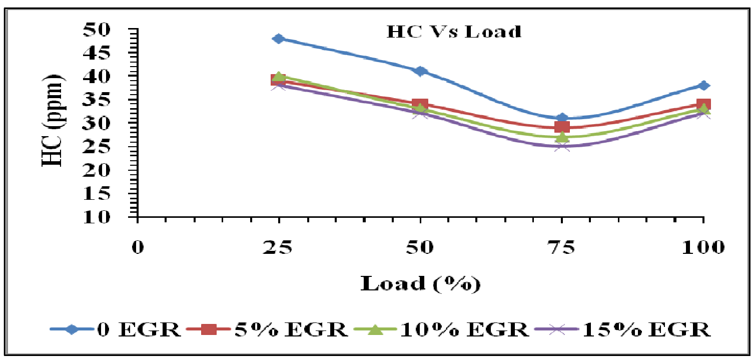

Figure 6.2.1 Variation of hydrocarbons with engine load

6.3 OXIDES OF NITROGEN (NOX):

6.3.1 MECHANISM OF NOX FORMATION

A major hurdle in understanding the mechanism of formation and controlling its emission is that combustion is highly heterogeneous and transient in diesel engines.While NO and NO_2 are lumped together as NOx, there are some distinctive differences between these two pollutants. NO is a colourless and odourless gas, while NO_2 is a reddishbrown gas with pungent odour. Both gases are considered toxic, butNO_2 has a level of toxicity 5 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.

NO is formed during the post flame combustion process in a high temperature region.The most widely accepted mechanism was suggested by Zeldovich. The principal source of NO formation is the oxidation of the nitrogen present in atmospheric air. The nitric oxide formation chain reactions are initiated by atomic oxygen, which forms

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from the dissociation of oxygen molecules at the high temperatures reached during the combustion process. The principal reactions governing the formation of NO from molecular nitrogen are,

$$N_2 + O_2 = NO + N;$$
$$N + O_2 = NO + O;$$
$$N + OH = NO + H$$

Chemical equilibrium consideration indicates that for burnt gases at typical flame temperatures,
NO_2 / NO ratios should be negligibly small. While experimental data show that this is true for spark ignition engines, in diesels, NO_2 can be 10 to 30% of total exhaust emissions of oxides of nitrogen. A plausible mechanism for the persistence of NO_2 is as follows. NO formed in the flame zone can be rapidly converted to NO_2 via reactions such as

$$NO + HO_2 + NO_2 + OH:$$

Subsequently, conversion of this NO_2 to NO occurs via

$$NO_2 + O = NO + O_2;$$

unless the NO_2 formed in the flame is quenched by mixing with cooler fluid. This explanation is consistent with the highest NO_2 / NO ratio occurring at high load in diesels, when cooler regions which could quench the conversion back to NO are widespread.
The local atomic oxygen concentration depends on molecular oxygen concentration as well as local temperatures. Formation of NOx is almost absent at temperatures below 2000 K. Hence any technique, that can keep the instantaneous local temperature in the combustion chamber below 2000 K, will be able to reduce NOx formation.

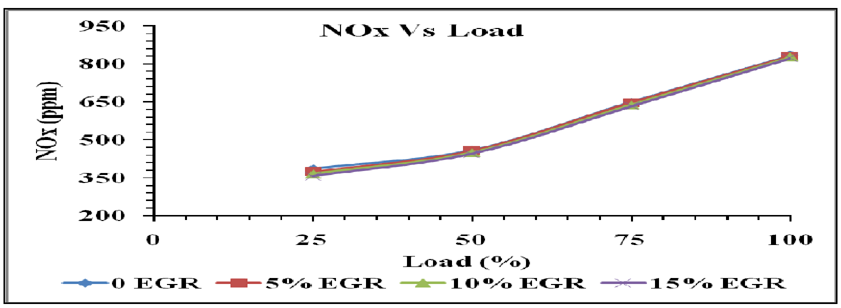

Figure 6.3.1.1Variation of oxides of nitrogen with engine load

Figure 6.3.1.1shows the variations of NOx emissions of the engine with and without EGR. The degree of reduction in NOx at higher at higher loads. The reasons for reduction in NOx emissions using EGR in diesel engines are reduced oxygen concentration and decreased the flame temperatures in the combustion chamber.

CONCLUSIONS

The main objective of the present investigation was to evaluate suitability of Exhaust Gas Recirculation system for use in a C.I. engine and to evaluate the performance and emission characteristics of the engine. In this thesis the performance and emission characteristics of diesel fuel with exhaust gas recirculation were investigated. The results obtained of this study are summarized as follows.

1. From the above figure it is clear that the value of Fuel Consumption of the diesel engine with EGR increases than that of without EGR system at same brake power.
2. The Brake Thermal Efficiency (BTE) of the engine was partially lower and the Brake Specific Fuel Consumption (BSFC) of the engine was partially higher when EGR system was implemented with engine.
3. The engine performance on EGR system, Exhaust Gas Temperature reduces as compared to that of without EGR system, so it is beneficial for surrounding.
4. Compared with conventional diesel fuel, the exhaust NOx was reduced about 25% at 15% EGR due to less oxygen available in the recirculated exhaust gases which lowers the flame temperature in the combustion chamber. Emission of Oxide of Nitrogen (NOx) was very much reduced by implementation of EGR system.
5. The total unburnt HC and CO emissions were decreased by 5 % and 10 % for diesel fuel with EGR and smoke emissions were observed as increases, due to incomplete combustion. Emission of Hydro Carbon (HC) increases by implementing EGR system with engine than that of operating engine without EGR system.

REFERENCES

1. Avinash Kumar Agarwal, Shrawan Kumar Singh, Shailendra Sinha And Mritunjay Kumar Shukla, "Effect of EGR on the exhaust gas temperature and exhaust opacity in compression ignition engines", Sadhana Vol. 29, Part 3, June 2004, pp. 275–284.
2. K. Rajan, K. R. Senthilkumar, "Effect of Exhaust Gas Recirculation (EGR) on the Performance and Emission Characteristics of Diesel Engine with Sunflower Oil Methyl Ester", Jordan Journal of Mechanical and Industrial Engineering. Volume 3, Number 4, Dec 2009, pp 306-311.
3. Pooja Ghodasara , Mayur Ghodasara , "Experimental Studies on Emission and Performance Characteristics in Diesel Engine Using Bio-Diesel Blends and EGR (Exhaust Gas Recirculation)", International Journal of Emerging Technology and Advanced Engineering, Volume 2, Issue 2, February 2012,pp 246-250.
4. G S Hebbar, Anant Krishna Bhat , "Performance and Emission of a Single Cylinder Stationary Diesel Engine with Exhaust Gas Recirculation", International Journal of Management, IT and Engineering, Volume 2, Issue 8, August 2012,pp 211-222.
5. B. Lakshmana Swamy, B. Sudheer Prem Kumar, K. Vijay Kumar Reddy, "Reduction of Diesel Engine Emissions and Its Analysis by Using Exhaust Gas Recirculation at Various Cooling Rates", International Journal of Engineering and Innovative Technology (IJEIT),Volume 3, Issue 2, August 2013,pp 224-228.
6. Pooja Ghodasara , M.S. Rathore , "Prediction on Reduction of Emission of Nox In Diesel Engine Using Bio-Diesel Fuel and EGR (Exhaust Gas Recirculation) System", International Journal of Mechanical Engineering, Volume 1 Issue 1, pp 18-25.
7. Hardik B. Charola, C. D. Sankhavara, M.B. Charola "Evaluate the Performance and Emission using EGR (Exhaust gas recirculation) in Compression-ignition engine fuelled with blend", IOSR Journal of Mechanical and Civil Engineering, Volume 10, Issue 5 , January 2014, pp 16-21.
8. A. Paykani, A. Akbarzadeh and M. T. Shervani Tabar, "Experimental Investigation of the Effect of Exhaust Gas Recirculation on Performance and Emissions Characteristics of a Diesel Engine Fueled with Biodiesel", International Journal of Engineering and Technology, Vol.3, No.3, June 2011, pp 239-243.
9. Kavati Venkateswarlu, Bhagavathula Sree Ramchandra Murthy and Vissakodeti Venkata Subbarao ,"The Effect of Exhaust Gas Recirculation and Di-Tertiary Butyl Peroxide on Diesel-Biodiesel Blends for Performance and Emission Studies", International Journal of Advanced Science and Technology, Vol. 54, May 2013, pp 49-60.
10. Deepak Agarwal, Shailendra Sinha, Avinash Kumar Agarwal, "Experimental investigation of control of Nox emissions in biodiesel-fueled compression ignition engine" , Renewable Energy , 31 , 2006, pp 2356–2369.
11. K. Venkateswarlu, B.S.R. Murthy, V.V. Subbarao and P. Sai Chaitanya, "An Experimental Investigation on the Combined Effect of Exhaust Gas Recirculation and Cetane Improver on Biodiesel-fueled Diesel Engine", International Energy Journal, 13, 2012, pp 133-144.
12. Gurumoorthy S. Hebbar, Anantha Krishna Bhat, "Diesel Emission Control by Hot EGR and Ethanol Fumigation; an Experimental Investigation", International Journal of Modern Engineering Research, Vol.2, Issue.4, July-Aug 2012 pp 1486-1491.
13. Ming Zheng , Graham T. Reader , J. Gary Hawley ,"Diesel engine exhaust gas recirculation—a review on advanced and novel concepts", Energy Conversion and Management 45 , 2004,pp 883–900.
14. K. Rajan, K. R. Senthilkumar ,"Effect of Exhaust Gas Recirculation (EGR) on the Performance and Emission Characteristics of Diesel Engine with Sunflower Oil Methyl Ester", Jordan Journal of Mechanical and Industrial Engineering, Volume 3, Number 4, December 2009,pp 306 – 311.
15. M.P. Poonia , Y.B. Mathur, "Effect of Exhaust Gas Recirculation on the Combustion of an LPG Diesel Dual Fuel Engine", Engineering Science and Technology: An International Journal (ESTIJ), ISSN: 2250-3498,Vol.2, No. 4, August 2012, pp 616-626.
16. Zuhdi Salhab ,"Effect of Exhaust Gas Recirculation on the Emission and Performance of Hydrogen Fueled Spark- Ignition Engine", Global Journal of Researches in Engineering Automotive Engineering, Volume 12 Issue 2 Version 1.0 , 2012 ,pp 18-24.
17. N. Ravi Kumar, Y. M. C. Sekhar, and S. Adinarayana, "Effects of Compression Ratio and EGR on Performance, Combustion and Emissions of Di Injection Diesel Engine",
18. J.M. Desantes, J. Galindo, C. Guardiola, V. Dolz, Air mass flow estimation in turbocharged diesel engine from in-cylinder pressure measurement, Exp. Therm. Fluid Sci. 34 2010, pp 37–47.