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EVALUATION OF ENGINE PERFORMANCE & EMISSION OF CI ENGINE UNDER COMBINED EFFECT OF INCREASING INTAKE BOOST PRESSURE AND EXHAUST GAS RECIRCULATION

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ABSTRACT

In this research, experiment was conducted to measure the engine performance and engine emission by combine effect of increasing boost pressure arrangement and EGR system. The engine performance like brake specific fuel consumption, brake thermal efficiency, exhaust gas temperature and emission like NOx, CO, HC and CO2 were measured and analyzed. It was seen that better result were observed on engine performance and NOx emission with combine effect of increasing boost pressure arrangement and EGR system as compared to individual EGR system. The EGR system was developed and tested with different EGR percentages, i.e. 0%, 10%, 15% and 20%. The effect of EGR on exhaust gas temperature and performance parameters like brake specific fuel consumption and brake thermal efficiency was studied. The performance and emission characteristics of the modified engine were compared with those of the conventional diesel engine. The results showed that EGR led to a decrease in specific fuel consumption and an increase in brake thermal efficiency. It is also found from the experiment, that at combination of 10% EGR rate and 160 kPa air intake boost pressure, maximum value of and minimum value of BSFC is obtained. It is 38.14% as brake thermal efficiency and 0.221 (kg/kWhr) as BSFC.

Keywords: Exhaust Gas Recirculation (EGR), Brake Specific Fuel Consumption (BSFC), engine performance, emission, Exhaust Gas Temperature.

Introduction

The Energy Consumption has been increased due to rapid growth in Industrialization and Individual mobility in today's World. Such causes a growth in transportation sector owing increased fuel consumption and environmental problems. The engineers are continuously developing the power units for the fulfillment of the industrial growth and to provide transportations.

Engine Emission

Because of its good fuel economy and high reliability, diesel engines have been penetrating a number of markets around the world. The diesel engines are used widely in heavy-duty engine applications (i.e. trucks, bus, power generation, etc.). They are preferred over spark ignition engines because they can achieve greater efficiencies and higher indicated mean effective pressures due to the higher compression ratios where they operate.

But the diesel is one of the largest contributors to environmental pollution problems worldwide, and will remain so, with large increases expected in vehicle population and vehicle miles travelled (VMT) causing ever-increasing global emissions. Diesel emissions contribute to the development of cancer; cardiovascular and respiratory health effects; pollution of air, water, and soil; soiling; reductions in visibility; and global climate change.

Diesel-powered vehicles and equipment account for nearly half of all nitrogen oxides (NOx) and more than two-thirds of all particulate matter (PM) emissions from transportation sources. Diesel emissions of nitrogen oxides contribute to the formation of ground level ozone, which irritates the respiratory system, causing coughing, choking, and reduced lung capacity. Ground level ozone pollution, formed when nitrogen oxides and hydrocarbon emissions combine in the presence of sunlight, presents a hazard for both healthy adults and individuals suffering from respiratory problems.

Developed countries and several later developing countries have adopted legislation for emission control to reduce air pollution. Therefore, achieving combustion at reduced nitric oxide emission with best technique has drawn increased attention. Hence according their own situation each of these countries has set their particular standard by pollution law for different kind of vehicle. Since the year 2000, India started adopting European emission and fuel regulations for four-wheeled light-duty and for heavy-duty vehicles. Indian own emission regulations still apply to two- and three-wheeled vehicles.

Exhaust gas recirculation (EGR)

Exhaust gas recirculation (EGR) into the engine intake is an established technology to reduce NOx emissions. The decrease of NOx emissions with EGR is the result of complex and sometimes opposite phenomena occurring during combustion. Exhaust gas recirculation (EGR) systems were introduced in the early '70s to reduce an exhaust emission that was not being cleaned by the other smog controls. The EGR system routes small quantities, usually between 6% and 30% of exhaust gas to the intake manifold. The re-circulated exhaust gas to the intake manifold. The result is a lower peak combustion temperature. As the combustion temperature is lowered, the production of oxides of nitrogen is also reduced.

Literature Review

Many researchers have been carried out on increase the boost pressure and EGR system.

Deepak Agarwal et al (2011) Two cylinders, direct injection constant speed of 1500 rpm was used for experiment. The engine was operated for 96 hours in normal running conditions and the deposits on vital engine parts were assessed. The engine was again operated for 96 hours with EGR and observations were recorded.

Tests were conducted at different EGR rate of 0%, 10%, 15% and 20% with different engine loads. For recirculation of exhaust gas, appropriate plumbing was done and quantity of exhaust gas control by control valve. They concluded that thermal efficiency for EGR was higher for lower loads. 15% EGR rate is found to be more effective to reduce NO_x emission without deteriorating engine thermal efficiency, BSFC, and emission. Higher EGR rates can be applied for lower loads. EGR can be applied to diesel engine without sacrificing its efficiency and fuel consumption with reduction in NO_x emission. Increase in CO, HC and PM emissions can be reducing by after treatment such as catalytic converter. Higher soot deposits were observed at cylinder head, injection tip and piston crown by using EGR.

G.H. Abd-Alla at el (2002) conducts experimental investigation on EGR and found that adding EGR to the air flow rate to the Diesel engine, rather than displacing some of the inlet air, appears to be a more beneficial way of utilizing EGR in Diesel engines. This way may allow exhaust NOx emissions to be reduced substantially. At constant burn duration and brake mean effective pressure, the brake specific fuel consumption decreases with increasing EGR. The improvement in fuel consumption with increasing EGR is due to three factors: firstly, reduced pumping work; secondly, reduced heat loss to the cylinder walls; and thirdly, a reduction in the degree of dissociation in the high temperature burned gases. Cooled EGR gives lower thermal efficiency than hot EGR but makes possible lower NO_X emissions. The use of EGR is, therefore, believed to be most effective in improving exhaust emissions.

Jaffar Hussain et al(2012) has been investigated the effect of EGR on performance and emissions in a three cylinders, air cooled and constant speed direct injection diesel engine, which is typically used in agricultural farm machinery. Such engines are normally not operated with EGR. 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, Brake Specific Fuel Consumption, and emissions. At lower loads, EGR reduces NOx without deteriorating performance and emissions.

Rizalman Mamat et al **(**2009) have studied the Effect of Air Intake Pressure Drop on Performance and Emissions of a Diesel Engine Operating with Biodiesel and Ultra Low Sulphur Diesel (ULSD). They were analyzed the engine performance and exhaust emission at combustion process in terms of cylinder pressure and heat release, an experimental evidence showed that, pressure drop increasing in the intake manifold will increase the fuel consumption and reduces the engine efficiency. They investigated the effect of air intake pressure drop on the engine performance and emissions of a V6 diesel engine.

Investigation concluded that the increase of pressure drop resulted to increase bsfc and reduces the engine efficiency at low load and part load. The exhaust emission of NOx is slightly decreased at low load due to longer of ignition delay. While at part load, the function of Air Fuel Ratio is significant to the formations of NOx rather than ignition delay thus promoted to increase NOx as pressure drop increase

Problem Formulation

From above experiment and investigation carried by various researchers conclude that the EGR is most effective technique to reduce engine tail pipe emission. Different parameter has different effect on the engine performance and emission. When EGR is combined with the other parameters like boost pressure, inlet air temperature, exhaust gas temperature, etc. it have different effects on performance and emission. The scope of work is associated with the experimental investigation on combined effect of EGR and increasing boost pressure on engine performance and emission. EGR have many positive and negative effects on the engine performance and emission. So, main motive for this study is to understand these effects.

The objective of this study is to find out the combined effect of increasing boost Pressure of air and EGR rate on performance and emission of four stroke diesel engines and by analyzing different values to improve the engine performance and reducing the NOx emission.

The objectives of the study are:

1. Finding the effect of EGR rates on engine performance and emission and combined effect of boost pressure and EGR rate on engine performance and emission.
2. In this research work, the performance parameters like brake efficiency, brake specific fuel consumption and engine emission of NOx, HC and CO will be measured and presented.
3. Compare the results obtained in the cases mentioned above and analyse the effect of EGR.

Experimental Setup Description

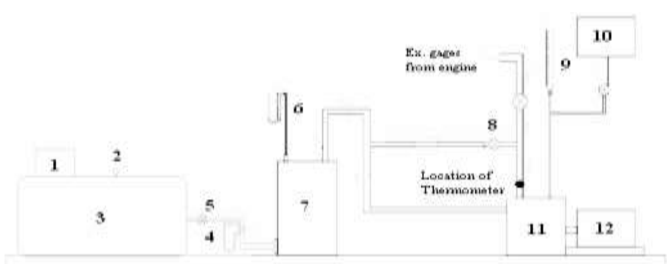

Fig.1: Line diagram of engine setup

1. Pressure gauge, 2. Compressor motor 3. Two stage reciprocating air compressor, 4. Orifice plate connected with U-tube manometer, 5.Compressor discharge valve, 6.U-tube manometer, 7. Surge tank, 8.EGR regulating valve, 9.Burette for the fuel flow measurement, 10.Fuel tank, 11.Diesel engine, 12.Rope brake dynamometer.

A 5 hp, single-cylinder, diesel engine is used for the experiment. A rope brake type dynamometer is coupled through load cell with engine. Piping arrangement were made for exhaust gas recirculation in engine. Two valves are provided in the exhaust circuit to obtain required mass flow EGR. On exhaust gas pipe line insulation was provided so re-circulated exhaust gases to cool down.

The line diagram of Engine set up is given in figure 1, 5 hp a single cylinder diesel engine used for experiment, Exhaust gas analyzer using the measurement of CO, CO_2, HC and NOx. For this experiment reciprocating compressor used to boosting the pressurized inlet air. Air tank, pressure gauge, orifice plate connected U-tube manometer was installed.The specifications of the engine as follows.

Table 1: Engine Specification

Parameter	Specification
Engine	Single cylinder high speed DI diesel engine
Rated speed	1500 rpm
Bore x stroke	80 mm x 110 mm
Compression ratio	16 : 1
Maximum power	5 hp or 3.7 kW
Capacity	553 CC

Experimental Procedure

In this experiment, diesel engine is used and connected with the rope brake dynamometer, varies the load on the engine or load remain constant. In this study a reciprocating two stage air compressor was used. A five gas analyzer is used to measure the emission characteristics of exhaust gas. The readings are taken at constant load or varying the load on engine using the dynamometer. The three load ranges from 0 kg to 17 kg were selected for the experiment.

Engine performance such as brake power; brake specific fuel consumption, brake thermal efficiency, exhaust gas temperature etc. and engine emission such as NOx, HC, CO and CO_2 found from the experiment. First diesel fuel is used at atmospheric inlet air pressure only and emission characteristics and engine performance is observed from the experiment. The three different EGR rates 10%, 15% and 20% were taken into account. Then these different EGR rates at atmospheric pressure are taken into account and finally three inlet air pressures were taken into account for one rate of EGR. So, in this experiment three boost pressure 120 kPa, 140 kPa and 160 kPa were taken for each EGR rate.

Gas analyzer is used to measure CO, HC, CO_2, O_2 and NOx from engine exhaust.

In order to achieve m_{EGR}, a common practice is to measure the mass air flow (m_{MAF}). By assuming a mass flow rate of cylinder the air flow rate of the EGR will determine by mass conservation on operating condition.

$m_{EGR} = m_{int} - m_{MAF}$

The estimation of such mass flow rate of the cylinder charge is stuck by other no of parameters like EGR temperature, pressure, engine block temperature, etc. But such parameters are not monitored when air flow is supplied. At higher levels EGR suppress flame speed sufficiently that combustion becomes incomplete and increased level of particulate matter (PM) and hydrocarbons (HC) are released in the exhaust.

RESULT AND DISCUSSION

Performance Analysis

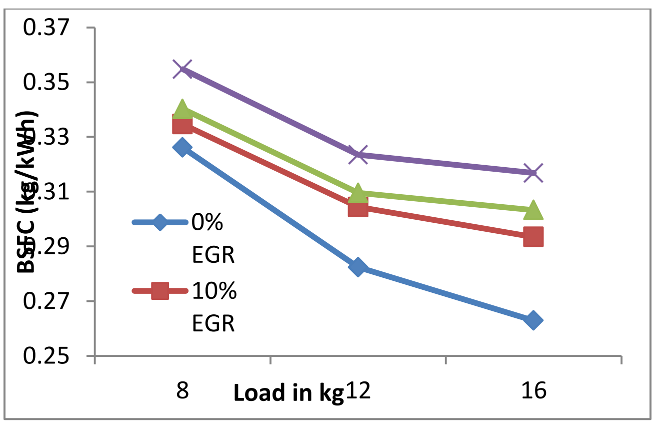

Figure 2: Brake specific fuel consumption at atmospheric inlet air pressure for different EGR rates.

Fig 2 shows BSFC at atmospheric intake boost pressure for varying EGR. The Brake specific fuel consumption increasing with increasing EGR rate because the oxygen available in air is reduced for combustion and change the fuel-air ratio and this increases the brake specific fuel consumption. Exhaust gas has high amount of CO2,is reducing maximum temp in combustion chamber with more EGR rate along with availability of oxygen so the not proper burning of fuel.

Figure 3 represents, the brake thermal efficiency decreases with the increasing EGR rate.

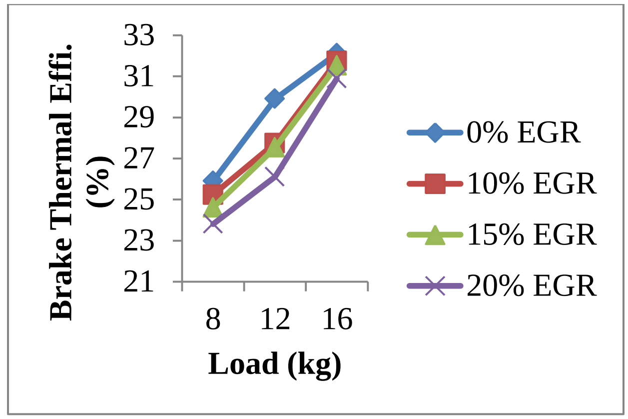

Figure 3: Brake thermal efficiency for different EGR rates at atmospheric inlet air pressure.

Figure 3 shows the exhaust gas temperatures for different EGR rate at atmospheric inlet air pressure. When the engine is operated with partly EGR, the exhaust gas temperature is reduced exhaust gas temperature decreases with EGR rate increasing because by EGR rate increasing oxygen availability is lower for combustion. It has been also observed that with increase in load, exhaust gas temperature is increased.

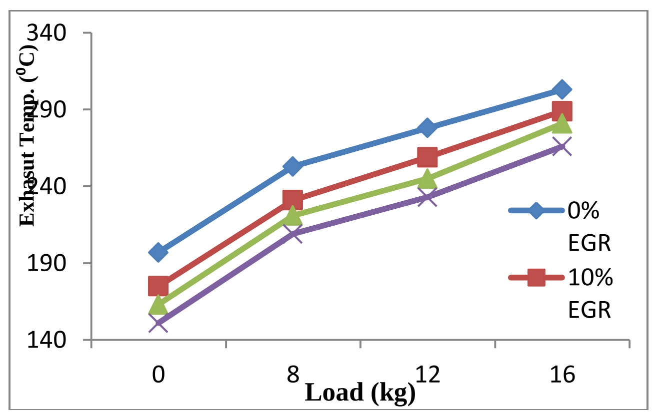

Figure 4 : Exhaust gas temperature at atmospheric inlet air pressure for different EGR rate.

Emission Analysis

Figure 5 represents the NOx emission for different EGR rates and varying loads of at atmospheric intake air boost pressure. This figure represents the main advantage of EGR system in reducing emission of NOx in diesel engine because of reduces the oxygen and lowered flame temperatures in the mixture.

The reduction NOx emission at higher load is high. The major effects on the combustion process the chemical effect, dilution effect and thermal effect. Due to H2Oand CO2 the specific heat of exhaust gas more, compare to normal air which is major content of N_2 and O_2 increasing the heat capacity of inlet charge, which result a reduce flame temperature during the combustion . While in dilution effect the combustion of O_2inside the cylinder is lowered which decelerate the mixing process between fuel and O_2 and fuel. Chemical the recirculateCO_2 and H_{2O} dissociate during this endothermic process and modify the combustion process and NOx formation.

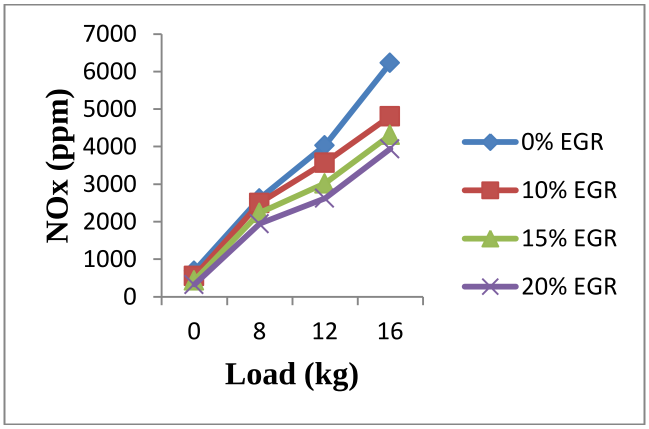

Figure5: Emission of NOx at atmospheric inlet air pressure for different EGR rates.

Figure 6, figure 7 and figure 8 represents the effect of different EGR rate on CO, HC and CO_2 emission at atmospheric intake air boost pressure for varying load condition.

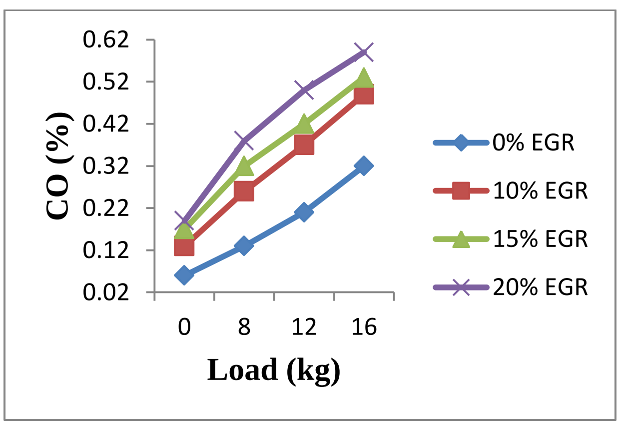

Figure 6: Carbon monoxide emissions at atmospheric inlet air pressure for different EGR rates.

It was observed increasing the EGR rate, the emission of HC, CO and CO_2 increases the reason may be with increasing EGR rate causes lower in oxygen concentration and reduced the combustion temperature this results in rich fuel-air mixtures at different locations in the combustion chamber and reduced the wall temperature. This heterogeneous mixture does not complete of combustion and in high HC,CO and CO_2 emissions.

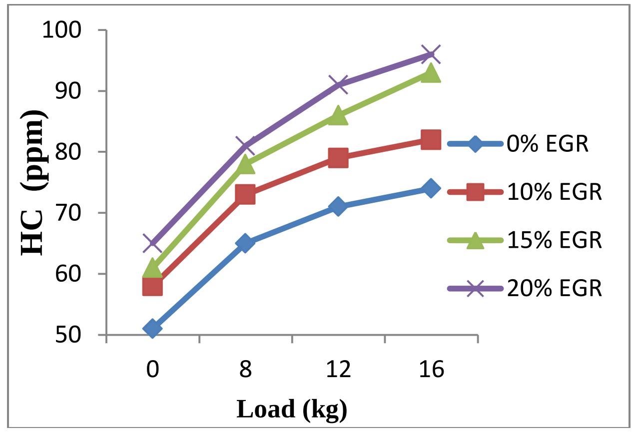

Figure :7 Hydro carbons at atmospheric inlet air pressure for different EGR rates and different loads.

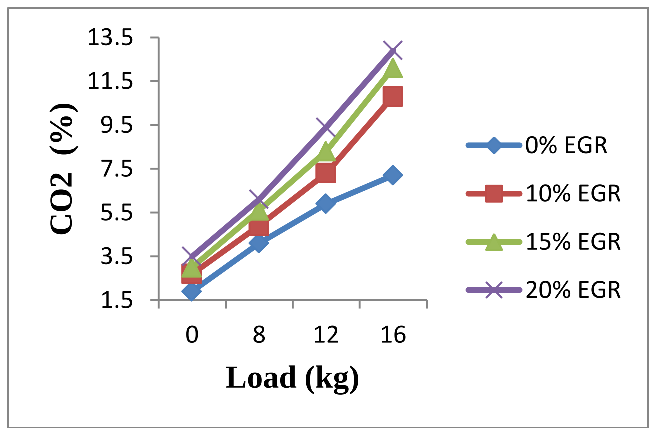

Figure 8: Carbon dioxide for different EGR rates.

In another experiment work was conducted for increasing intake air boost pressure with EGR and observes the different effect of EGR and increasing intake air boost pressure on the engine emission and performance.

Result and Discussion for Different EGR Rate and Increasing Boost Pressure of Inlet Air

The result of combine effect of increasing boost pressure and EGR system in diesel engine on the performance and emission. Basically increasing boost pressure lowers the BSFC, increases the brake thermal efficiency and reduces the NOx emission. But it also increases the emission of CO, HC and CO_2. The combine effect of EGR system and increasing boost pressure on engine performance like bsfc, brake thermal efficiency and exhaust gas temperature and on emission of engine like NOx, CO, HC and CO_2 obtained from the experiment are shown graphically below for fixed load condition 8 kg.

Performance Analysis

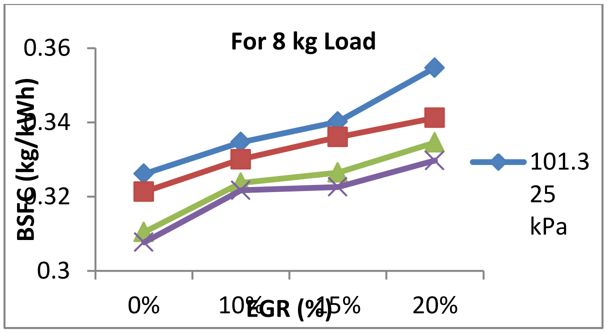

Fig 9

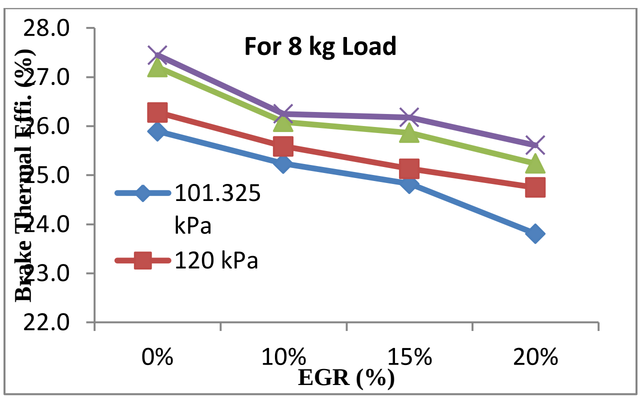

Fig 10

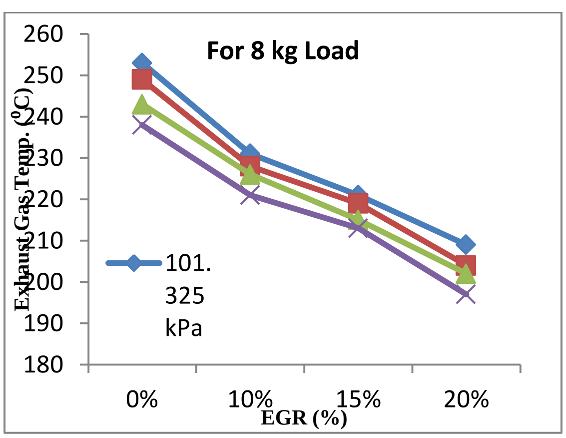

Fig 11

Emission Analysis

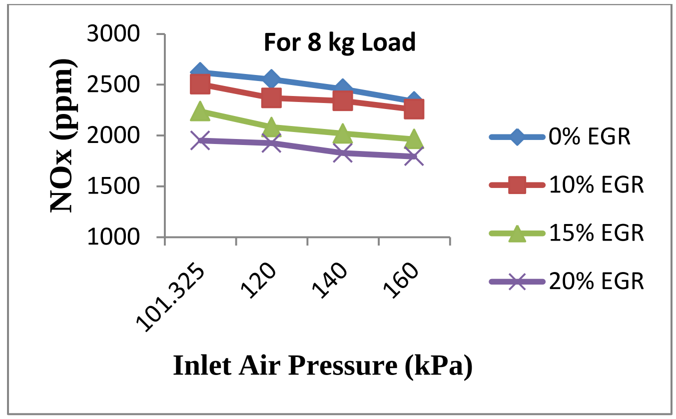

Fig12

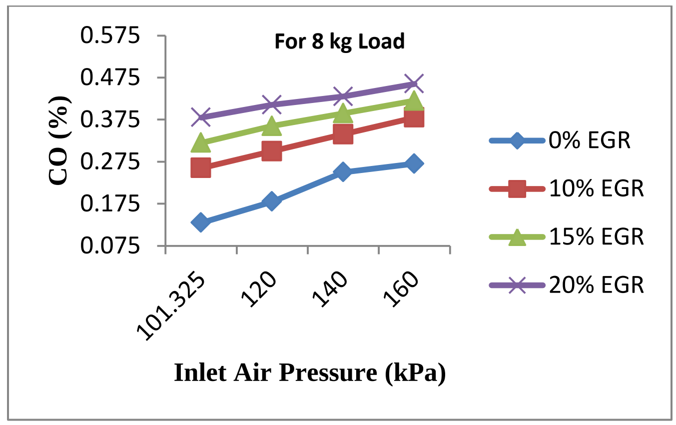

Fig13

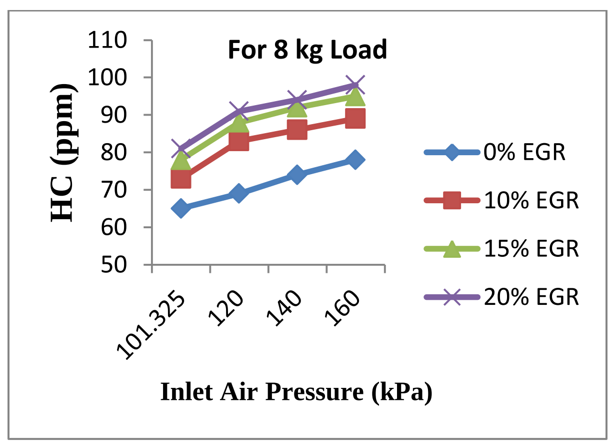

Fig14

So, from above results and discussion the negative and positive effect of combining boost pressure attachment and EGR system is illustrated. It has a positive effect on NOx formation by reducing it and also decreases BSFC and increase brake thermal efficiency compared to individual EGR system. But as a negative effect, it increases the CO, HC and CO_2 emission.

CONCLUSION

In this research experiment was conducted to measure the engine performance and engine emission by combine effect of increasing boost pressure arrangement and EGR system. The engine performance like brake specific fuel consumption, brake thermal efficiency, exhaust gas temperature and emission like NOx, CO, HC and CO_2 were measured and analyzed graphically. It observed better result on engine performance and NOx emission with combine effect of increasing boost pressure arrangement and EGR system than individual EGR system.

- The emission of NOx is reduced by increasing EGR rate but the emission of CO, CO_2, and HC is increased. By increasing EGR, Brake specific fuel consumption is increase and the brake thermal efficiency decrease, and the exhaust gas temp decrease.
- It was also observed increasing boost pressure with increasing EGR rate lowered more exhaust gas temperature than individual EGR system.
- By using exhaust after-treatment techniques, such as diesel oxidation catalysts (DOCs) and soot traps. The emission of CO, HC, and CO_2 can be reduced
- It is also found from the experiment, that at combination of 10% EGR rate and 160kPa air intake boost pressure, maximum value of η_{BTh} and minimum value of BSFC is obtained. It is 38.14% as brake thermal efficiency and 0.221 (kg/kWhr) as BSFC.
- Hence it is recommended to use the combined effect of 10% EGR rate and 160 kPa air intake boost pressure, so as to maximize performance. Other means may be employed to further reduce NOx emission. Please note that NOx emission is more in case of 0% EGR rate than 10% EGR rate.

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