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EFFECT OF EGR ON C.I ENGINE EMISSIONS AND COOLING RATE USING DIESEL AND ETHANOL BLENDS

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Abstract: *Emission control has become a major problem in the society and indiscriminate usage of motor vehicles increases a lot of pollution, mainly in cities. Diesel is a non-renewable energy source and used more than petrol or gasoline and also the emissions of the diesel engine create a lot of havoc especially ecological imbalance. According to the studies referred in the literature the use of bio- fuels especially ethanol along with EGR can reduce particulate matter and nitrogen oxide (NOx). The main aim of this paper is to evaluate the emission characteristics Nitrogen oxides (NOx), carbon dioxide (CO_2),carbon monoxide(CO),Hydrocarbons(HC)emissions of four stroke single cylinder diesel engine by using exhaust gas recirculation(EGR) at various blends of diesel, ehanol and propanol and also emissions of exhaust gas of Nitrogen oxides(NOx)), carbon Dioxide(CO_2), carbon monoxide(CO), Hydrocarbons (HC) emissions) using EGR at normal and varying the cooling rates at peak load.*

Keywords: *EGR, Ethanol, NOx, CO, Cooling rate, peak load*

1. INTRODUCTION

Increased fissile fuel consumption decreases the limited reserves of the world energy. About 71 barrels are burnt everyday throughout the world. And this consumption rate goes on increasing by 2% every year. The 2% doubles the quantity every 34 years. Somewhere between 1000 to 1600 billion barrels of fuel consumption are assumed to be in formation where economic recovery is possible. The current rate of consumption 1600 billion barrels would be depleted in 60 years.

There were many attempts made to use bio-fuels in compression ignition engine. Jincheng Huang et al.(2008)[15]carried out tests to study the performance and emissions of the engine fuelled with the ethanol diesel blends. They found it feasible and applicable for the blends with n-butanol to replace pure diesel as the fuel for diesel engine. Bhattacharya and Mishra(2002)[16]evaluated the feasibility of preparing diesel-ethanol blends using anhydrous ethanol and ethanol and found ethanol blends indicate power producing capability of the engine similar to that of diesel. Hansen et al.(2001)[14]found that the properties of ethanol –diesel blends have a significant effect on safety, engine performance, durability and emissions[11]. Wang et al.(2003)analyzed that the most note worthy benefits of E-diesel use lie with petroleum fuel reductions in urban particulate matter and CO emissions by heavy vehicle operation.

Coming to output of an IC engines i.e the emissions which have an adverse effect on environment by causing air pollution. Exhaust emissions of an automotive IC engine constitutes of oxides of Nitrogen (NOx),oxides of sulphur (SOx) oxides of carbon (CO and CO2),un-reacted oxygen, un-reacted Nitrogen, Un burnt Hydro carbons, particulate matter and water vapours etc., each of them have a specific indication on performance of the engine and effect on the environment.

Diesel exhaust contain several pollutants that contribute to the formation of ground level ozone, acid rain, and are harmful to public health alone or in combination with other substance. So to control emissions and to prolong the reserves of petroleum products experiment conducted using diesel and ethanol blends with EGR on Diesel engine.

2. EXHAUST GAS RECIRCULATION

EGR is commonly used to reduce NOx in S.I engines as well as C.I engines. The principle of EGR is to re circulate about 10% to 30 % of the exhaust gases back into the inlet manifold[6] where it mixes with the fresh air and this will reduces the quantity of O_2 available for the combustion. This reduces the O_2 concentration and dilutes the intake charge, and reduces the peak combustion temperature inside the combustion chamber which will simultaneously reduce the NOx formation. About 15% recycle of exhaust gas will reduce NOx emission by about 80%. It should be noted that most of the NOx emission occurs during lean mixture limits when exhaust gas recirculation is least effective. The exhaust gas which is sent into the combustion chamber has to be cooled so that the volumetric efficiency of the engine can be increased.EGR ration is defined as the ration of mass of recycled gases to the mass of engine intake. Also %EGR is from above three methods, EGR is most efficient and widely used system to control the formation of oxides of nitrogen inside the combustion chamber of I.C engine. The exhaust gas for recirculation is taken through an orifice and passed through control valves for regulation of the quantity of recirculation. Normally exhaust gas recirculation is shutoff during idle to prevent rough engine operation. EGR is a very useful technique for reducing the NOx emission. EGR displaces oxygen in the intake air and dilute the intake charge by exhaust gas re-circulated to combustion chamber. Re-circulated exhaust gas lower the oxygen concentration in the combustion chamber and increase the specific heat of the intake air mixture, which results in lower flame temperature. It was observed that 15% EGR rate is found to be effective to reduce NOx emission substantially without deteriorating engine performance in terms of thermal efficiency, Break specific fuel consumption (BSFC) and emissions .thus, if higher rate of EGR can apply at lower loads and lower rate of EGR can be applied at higher loads. EGR can applied to diesel engine fueled with diesel oil the diesel oil, bio diesel , LPG , Hydrogen etc., without sacrificing it efficient and fuel economy and NOx reduction can be thus achieved .EGR is useful technique for reducing NOx formation in combustion chamber. Exhaust consists of CO_2 .N_2 and water vapours 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 O2 in the combustion chamber. This specific heat EGR is much higher than the fresh air, hence EGR increase the heat capacity (sp.heat) of the intake charge, thus decreasing the temperature rise for the same heat release in the combustion chamber.

3. EXPERIMENTAL SETUP

This experimental work is to investigate the performance of single cylinder 4-stroke diesel engine connected to eddy current dynamometer fuelled with diesel oil with ethanol blends with EGR (14%, 20%, 28%) diesel fuel with blends under different load conditions and constant engine running speed. The emissions at normal and excess cooling rates [17] are studied with varying cooling rates in the experiment.

Fig. 1 shows EGR set to the Single cylinder Diesel Engine

3.1. ENGINE SPECIFICATION:

Table 1: Engine specifications

Type	4-stroke, single cylinder diesel engine
make	kirloskar av-1
rated power	3.7 kw, 1500 rpm
bore and stroke	80 mm×110 mm
compression ratio	16.5:1
cylinder capacity	553 cc
dynamometer	electrical-ac alternator
cylinder pressure	range:2000 psi or 140.000 bars
orifice diameter	15 mm
starting	auto start
cooling	water cooled

4. EXHAUST GAS ANALYSER

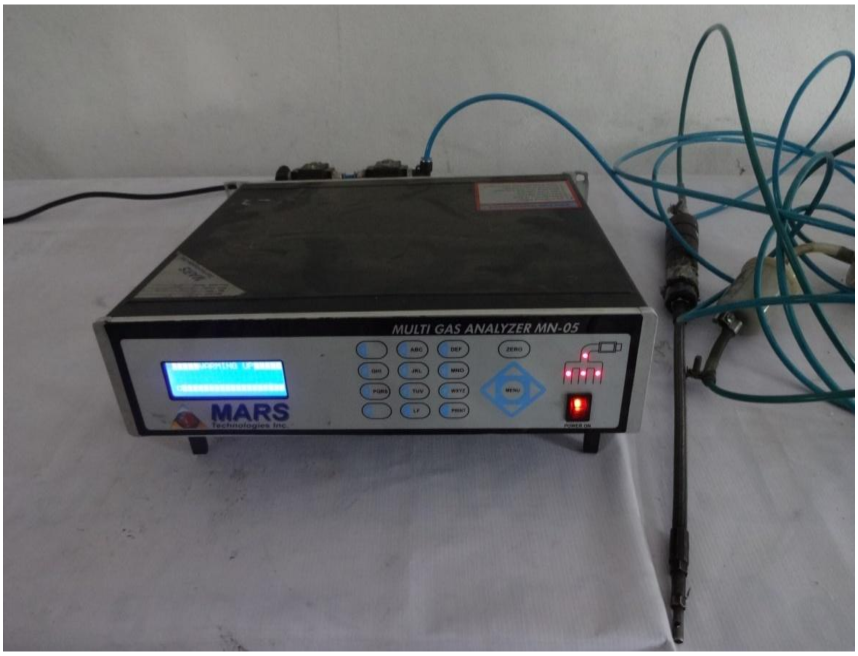


Fig. 2 Exhaust gas analyzer

The exhaust gas temperature is measured by thermocouple and the exhaust analyzer analyzes the emissions like HC, CO, NOx, CO_2 and O_2. Exhaust gas analyzer is of MN-05 multi gas analyzer (5 gas version) is based on infrared spectroscopy technology with signal inputs from an electrochemical cell. Non dispersive infrared measurement technique uses for CO, CO_2 and HC gases. Each individual gas absorbs infrared radiation absorbed and it can be used to calculate the concentration of the sample gas. Analyzer uses an electrochemical cell to measure the oxygen concentration. it consists of two electrodes separated by an electrically conducted liquid or cell. The cell is mounted behind a polytetrafluroethane membrane through which oxygen can diffuse. The device therefore measures oxygen partial pressures. If polarizing voltage is applied between electrodes the resultant current is proportional to the oxygen partial pressure.

5. EXPERIMENTAL ENGINE EMISSIONS READINGS

Exhaust gas emissions are studied with exhaust gas analyzer at peak load (3KW) for both diesel fuel and biodiesel fuel, with and without EGR and values are recorded as follows:

Biodiesel blended with diesel fuel in concentration of 10%, 20%, 30%, and in 100% by volume on single cylinder engine. At high loads using single injection, particle and CO_2 (carbon dioxide) and NOx (Nitrogen oxide) emission were decreased. A slight increase in CO was observed as the Cotton seed oil concentration is increased. HC (Hydrocarbons) at blend 1 will be decreased after blend 2 and 3 will be increased and O_2 (Oxygen) percentage will be increased. The performance, emission and combustion characteristics of biodiesel blends were evaluated on a single cylinder, four strokes, water cooled diesel engine

Table 2: Emission Characteristics for Pure Diesel

	0% EGR	14%EGR	20%EGR	28%EGR
CO in vol%	.100	0.066	0.066	0.074
O_2 in vol%	8.3	8.47	8.46	8.44
CO_2 in vol%	7.67	7.47	7.52	7.59
NO_x in PPM	00750	00764	00764	007545
HC in PPM	0131	0131	0128	0128

Table 3: Emission Characteristics for blend-1

	0% EGR	14%EGR	28%EGR
CO in vol%	0.212	0.174	0.154
O_2 in vol%	7.93	8.20	8.02
CO_2 in vol%	9.01	8.45	8.28
NO_x in PPM	00622	00671	00697
HC in PPM	0004	0030	0062

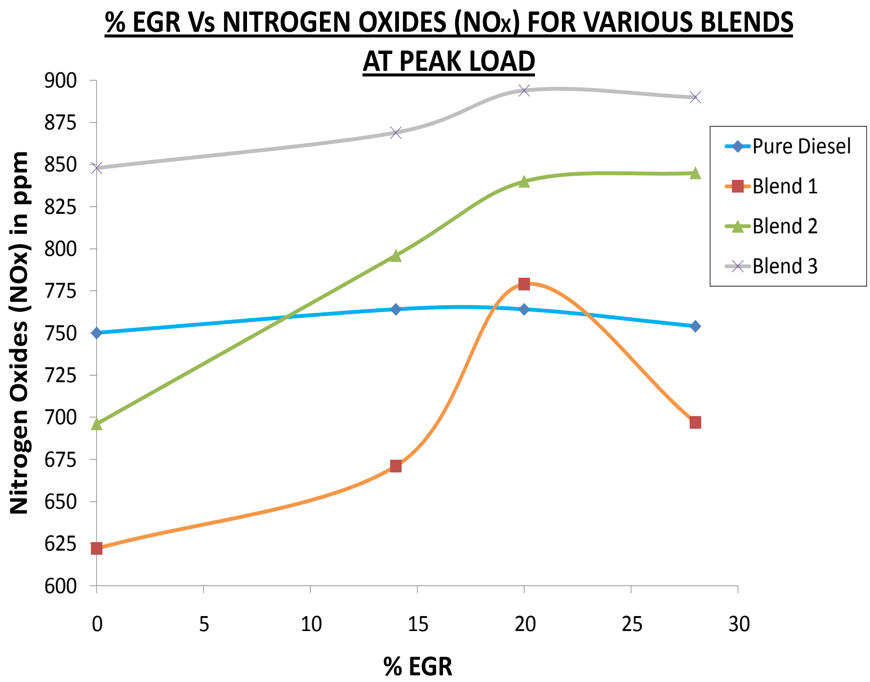
Table 4: Emission Characteristics for blend-2

	0% EGR	14%EGR	20%EGR	28%EGR
CO in vol%	0.108	0.118	0.088	0.085
O_2 in vol%	8.40	8.55	8.70	8.83
CO_2 in vol%	7.87	7.72	7.55	7.50
NO_x in PPM	00696	00796	00840	00845
HC in PPM	0083	0078	0084	0119

Table 5: Emission Characteristics for blend-3

	0% EGR	14%EGR	20%EGR	28%EGR
CO in vol%	0.079	0.080	0.063	0.058
O_2 in vol%	8.65	8.60	8.95	8.97
CO_2 in vol%	7.59	7.58	7.33	7.32
NO_x in PPM	00848	00869	00894	00890
HC in PPM	0129	0125	0128	0121

6. EMISSIONS CHARACTERISTICS

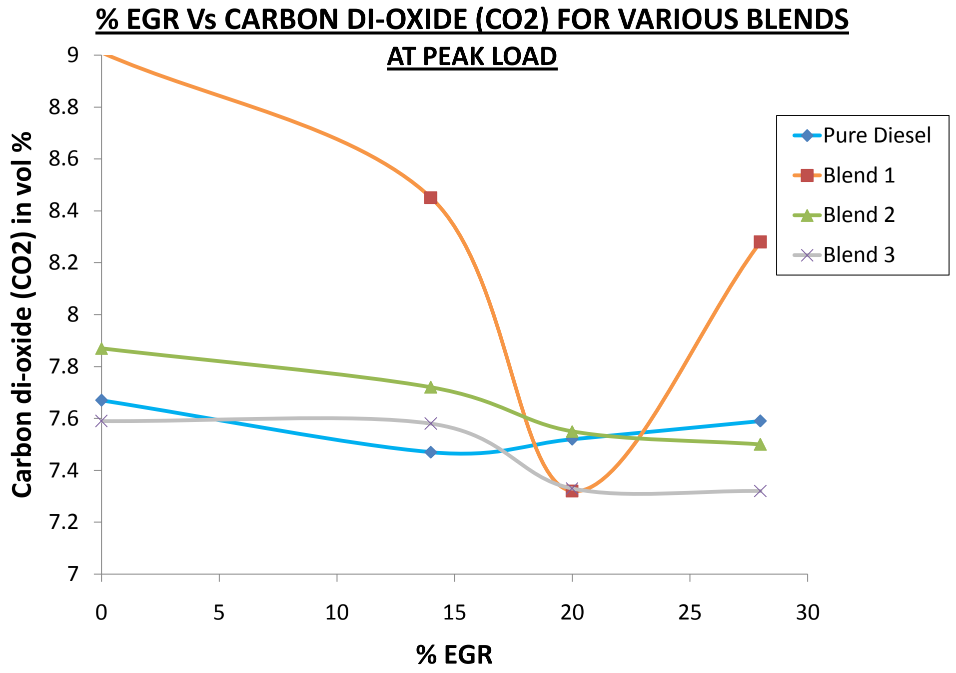


Graph 1: percentage of EGR vs Nitrogen oxide (NOx) for various blends at peak load

For pure diesel as the % EGR increases the NOx emissions increases up to 14% EGR and then it starts decreasing. The pattern of the graph shows that the NOx emissions for pure diesel almost remaining the same.

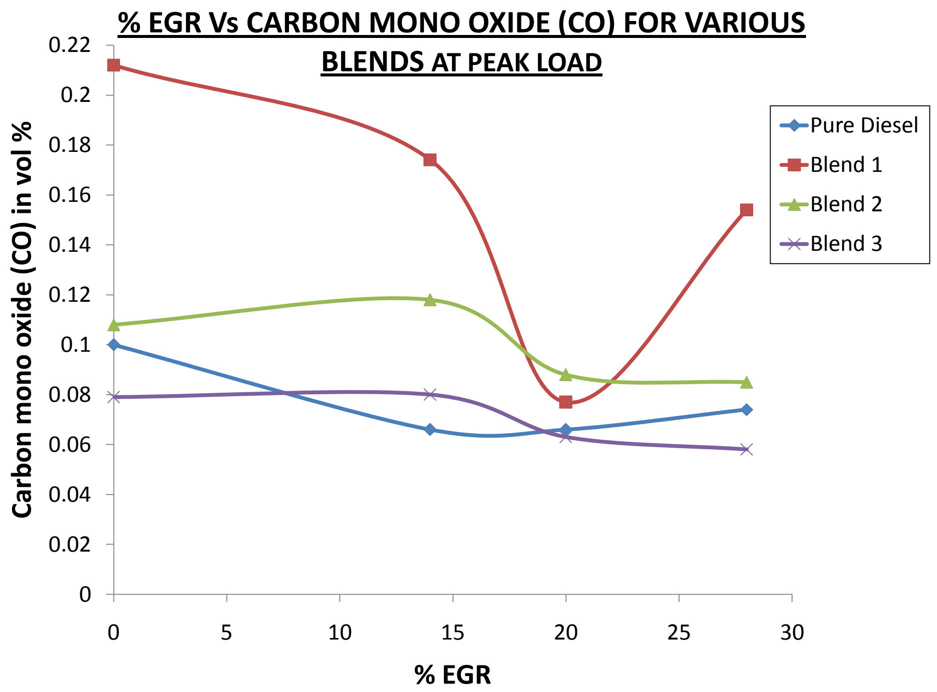
For blend -1 at 0% EGR there was a decrease of 17.06% NOx emission when compared to pure diesel at 0% EGR (750PPM)

For blend-1 at 14% EGR (671 PPM) there was a decrease of 12.17% when compared to pure diesel at 14% EGR (764PPM)



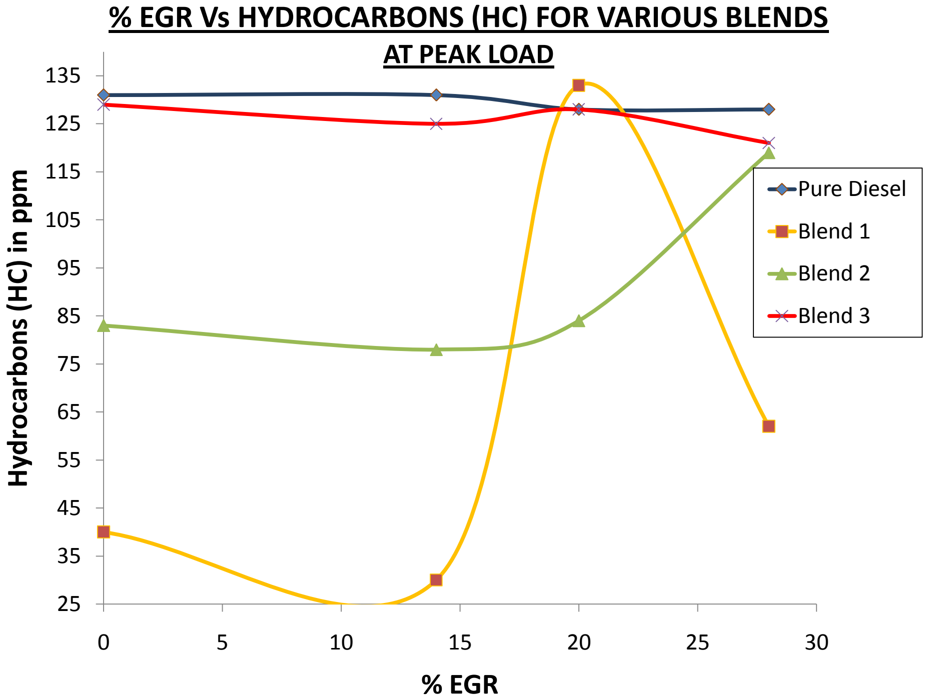
Graph 2: percentage of EGR vs carbon-dioxide (CO2) for various blends at peak load

The above graph shows that the carbon dioxide emissions decreased with the induction of EGR .the maximum reduction of carbon dioxide (CO_2) emissions in volume percentage was found for blend -1 at 20% EGR (7.32%) and blend 3 at 28% EGR (7.32%)



Graph 3: percentage of EGR vs carbon monoxide (CO) for various blends at peak load

Carbon mono oxide (CO) emissions in volume percentage decreased from 0% EGR (0.1%) to 20% EGR (0.066%) but by further induction of %EGR the CO emissions increased. The maximum reduction of CO emissions was for pure diesel at 14 % EGR, comparable with emissions for blend-1 at 20% EGR (0.077%) and blend 3 at 14 % EGR (0.08%)

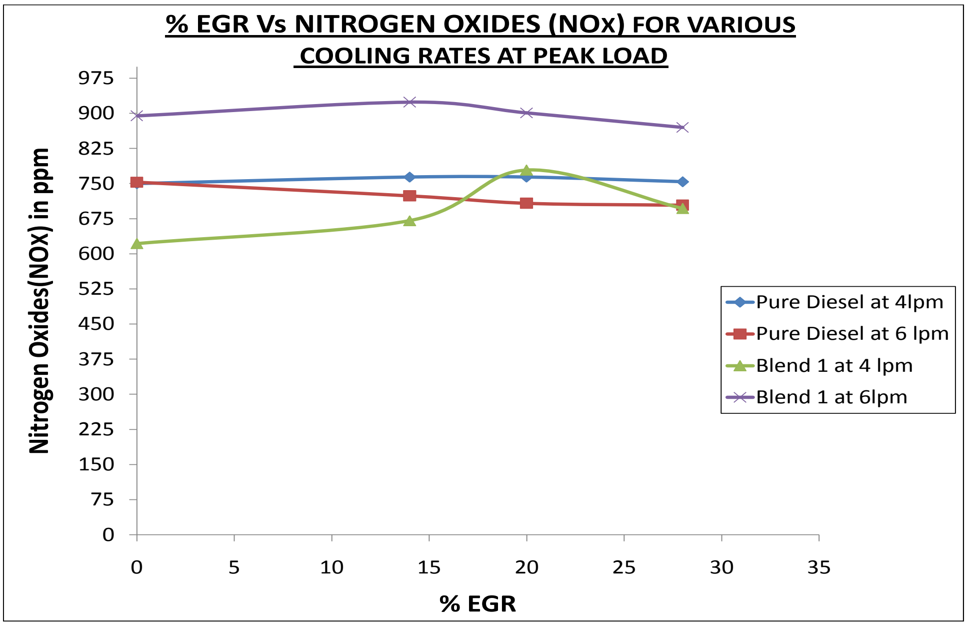


Graph 4: percentage of EGR vs Hydrocarbons (HC) for various blends at peak load

The graph depicts that there was not much reduction of hydrocarbons (HC) by increasing the %EGR for pure diesel. For Blend-1 at 14% EGR (30 PPM) there was a drastic decline of 77% HC emissions when compared to pure diesel at 14 % EGR (131 PPM). But after 20%EGR the HC emissions went on increasing and then decreased after reaching a specific value. i.e 133 PPM of HC

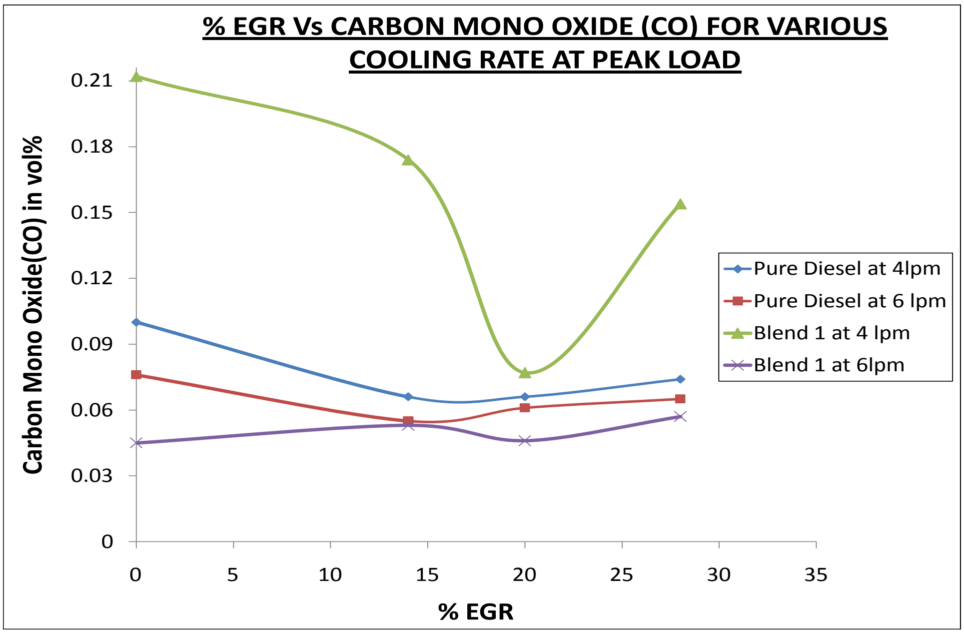
Blend-2 also showed good results compared to pure diesel between 14%EGR (78PPM) to 20% EGR (119PPM)

7. EMISSIONS AT NORMAL AND EXCESS COOLING RATES



Graph 5: percentage of EGR vs Nitrogen oxide (NOx)

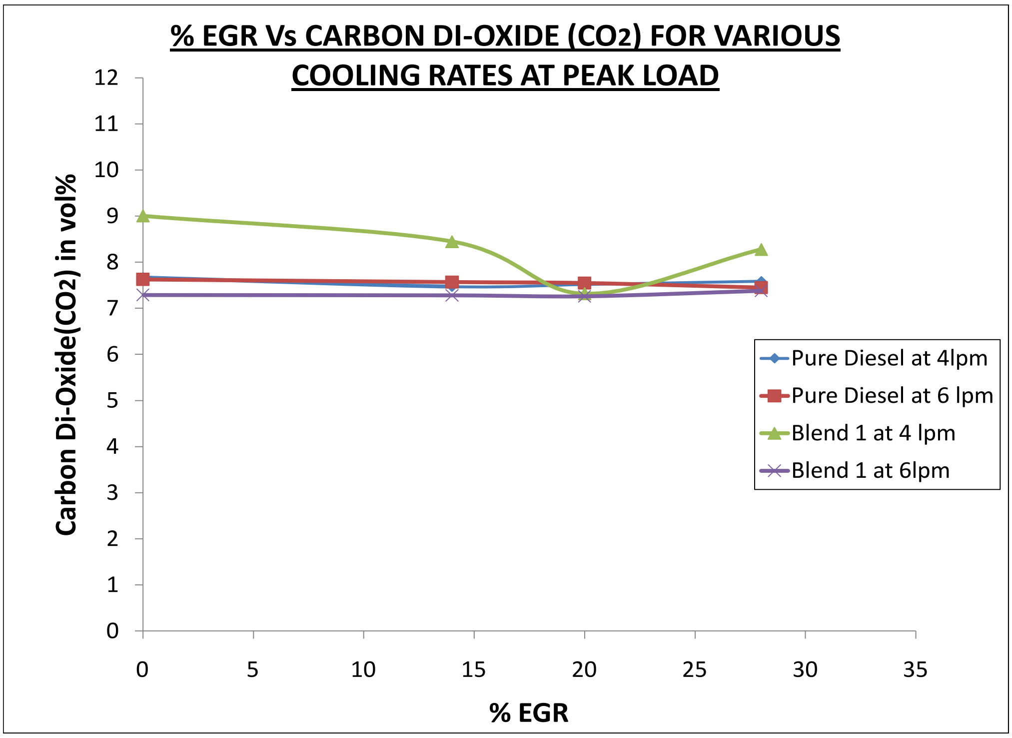
Pure diesel excess cooling rate i.e 6 LPM showed a decrease in nitrogen oxide(NOx)emissions by the induction of EGR when compared to pure diesel at normal cooling rate i.e 4 LPM. There was a reduction of 6.63%, NOx emissions from pure diesel at normal cooling rate at 28% EGR (754PPM) to pure diesel at excess cooling rate at 28 %EGR (704 PPM). The minimum NOx emission was observed for blend-1 at 0% EGR at normal cooling rate (4 LPM) i.e 622 PPM.



Graph 6: percentage of EGR vs Carbon monoxide (CO)

As the graph it shows that by providing excess cooling rate, there was a reduction in carbon monoxide (CO) emissions for both pure diesel and blend-1 individually. For pure diesel at excess cooling rate (6 LPM) the minimum CO emissions in volume % was recorded at 14 % EGR i.e 0.055% of CO, which means a reduction of 7.75% CO emission when compared to pure diesel at normal cooling rate (4 LPM) at 14%EGR(0.066% of CO)

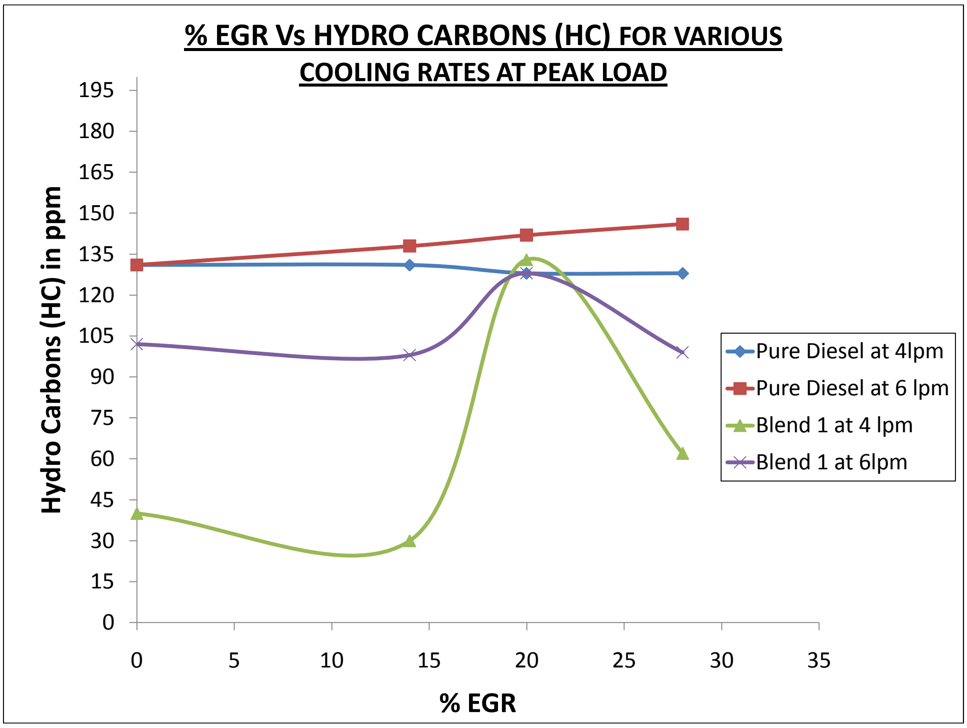
The least CO emission in all was observed for blend-1 at excess cooling rate (6 LPM) at 20%EGR i.e 0.046% of CO, which means a reduction of 40% CO emission when compared to blend-1 at normal cooling rate (4LPM) at 20% EGR(0.077% of CO).



Graph 7: percentage of EGR vs Carbon dioxide (CO2)

The minimum carbon dioxide emission in volume % was noted for blend -1 excess cooling rate (6LPM) at 20% EGR i.e 7.26% of CO2 ,which indicates a reduction of 0.81% CO2 emission when compared to blend-1 at normal cooling rate (4LPM) at 20% EGR (7.32% of CO2).

For pure diesel by providing excess cooling rate and EGR, there was a reduction of CO2 emission from pure diesel at normal cooling rate (4LPM) at 28% EGR i.e 7.59% of CO2 to pure diesel at excess cooling rate (6LPM) at 28% EGR i.e 7.45% of CO2.



Graph 8: percentage of EGR vs hydrocarbons (HC)

The minimum Hydro carbon (HC) emission was observed for blend-1 at normal cooling rate at 20% EGRi.e 30 PPM. The optimum result was obtained between 14%EGR and 20%EGR. For blend-1 there was a reduction of 3.75% HC emission from blend-1 at 20% EGR at normal cooling rate (4LPM)i.e. 133 PPM of HC to blend-1 at 20% EGR at excess cooling rate (6LPM) i.e 128 PPM of HC

8. CONCLUSIONS

Nitrogen oxide (NOx) emissions decreased by 17% by using blend-1 as fuel at 0%EGR compared to pure diesel

There was a reduction of 77 % of hydro carbon (HC) emissions by using blend-1 as fuel when compared to pure diesel.

The minimum carbon dioxide (CO2) emission was observed for blend-1 and blend-3 with the introduction of 20 % EGR

At excess flow rate (6 LPM) for engine having pure diesel as fuel, the nitrogen oxide (NOx) emission got reduced by 6% compared to normal flow rate (4LPM)

Carbon dioxide (CO2) emission decreased with the introduction of excess cooling rate and by using blend-1 as fuel when compared to normal cooling rate engine.

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