COMBINED IMPACT OF BIODIESEL (MENO) AND EXHAUST GAS RECIRCULATION ON NOX EMISSIONS IN DI DIESEL ENGINES

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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. The objective of this work is to find 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, air-cooled, constant speed direct injection diesel engine is used for experiments. HC, NOx, CO, and smoke of the exhaust gas are measured. Various engine performance parameters such as thermal efficiency, and brake specific fuel consumption are calculated from the acquired data. As the percentage of bio diesel increased in diesel and bio fuel blend the NOx emission increased. In order to reduce the emission from bio diesel EGR is used. Application of EGR with biodiesel blends resulted in reductions in NOx emissions without any significant penalty in smoke emissions. The results reveal that the Blend 100 (100 % bio fuel) produces maximum NOx emission (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

KEYWORDS: *NO_x, EGR, MENO, Injection pressure, and Crank angle.*

I. INTRODUCTION

Bio diesels are attractive alternatives to conventional fuels. They can be combined with diesel or used as sole fuel. As the biodiesel content increases the NOx emission also increases due to its higher oxygen content. [1]. Consequently, Diesel engine combustion generates large amounts of NOx because of the high flame temperature in the presence of abundant oxygen and nitrogen [2,3].There is a concern that the brake thermal efficiency may decrease with increasing EGR rates, however this decrease is marginal [4]. Experimental investigations were conducted by many researchers from methyl esters of sunflower oil [5]. Previous studies [6] show that diesel and bio diesel blends give lower carbon monoxide and smoke emissions but higher oxides of nitrogen (NOx) emissions as compared with conventional diesel fuel. Researchers [7-10] throughout the world are pursuing the usage of bio diesel as an alternate fuel in diesel engines. Bio diesel also improves engine lubrication and hence improves engine life. Straight vegetable oils or their blends with diesel pose various long-term operational and durability problems in compression ignition engines, e.g., poor fuel atomization, piston ring-sticking, fuel injector coking and deposits, fuel pump failure, and lubricating oil dilution, etc**.**

1.1 Mechanism of NOx formation

It is very difficult to theoretically estimate the exact quantity of NOx formed inside a Diesel engine due to its heterogeneous nature of combustion. While NO and NO_2 are lumped together as NOx , there are some distinctive differences between these two pollutants. NO is colourless and odourless gas, while NO_2 is a reddish brown gas with pungent odour. Both gases are considered toxic, but NO_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 The formation of NOx is explained by Zeldovich Mechanism.

II. EXPERIMENTAL SETUP

The experiment was conducted in a four strokes, two cylinder, and constant speed compression ignition engine. The engine was Simpson make and water cooled, vertical, direct- injection. The engine is coupled with a dynamometer. The specification of the engine is given in table 1. At the rated speed (1500RPM), the engine develops approximately 7.46 KW (10 HP) power output. The objective of developing this experimental test setup is to investigate and demonstrate the effects of various EGR rates and other engine parameters on exhaust emissions from the engine. A long route hot EGR system is chosen based on its merits. Several components of this EGR system have been designed and fabricated.

Table I. Engine Specifications

Type	Vertical inline diesel engine
No – of cylinder	2
Bore	91.4 mm
Stroke	127mm
Displacement	1670 cc
Compression ratio	18.5:1
Cycle	4 stroke
Power	7.46 k w (10 H.P)
Speed	1500RPM
Orifice diameter	22 mm
Combustion system	Direct injection
Cooling system	Water cooling
Loading device	Swing field dynamometer

An air box is designed to measure the volumetric flow rate of intake air to the engine. It is mounted on the inlet pipe between the air filter and the inlet manifold of the engine as shown in Fig. 1. The air box dampens out the fluctuations of the intake air. A diaphragm is provided on the side of the air box for dampening out the local undulations effectively. The air box is fitted with an orifice (shown in fig 1) for volumetric flow rate measurement of air. A U-tube manometer is mounted across the orifice, to measure the pressure difference inside the air box and the atmosphere. The coefficient of discharge of the orifice is found experimentally to be 0.602. The properties of diesel and Bio diesel used in the experimentation are given in the table 2

Table 2 Properties of Diesel and Neem Oil

PROPERTIES	DIESEL	NO	MENO
Density (kg m−3)	830	912-965	820-940
Viscosity(cSt)	4.7	20.5-48.5	3.2-10.7
Flash point(◦C)	60	214	120
Cetane number	45	31-51	48-53
Calorific value(MJkg−1)	42	32-40	39.6-40.2

Sulfur (ppm)	0.042	1990	473.8
Saponification value	-	175-200	-
Iodine value	-	65-80	-
Titre (◦C)	-	35-36	-
Fire point (◦C)	65	222	128
Pour point (◦C)	-16	10	2
Cloud point (◦C)	-12	19	9
Total glycerine (%)	-	-	0.26
Free glycerine (%)	-	-	0.02
Oxidation stability (h), 110 ◦C	3-6 min	12.4	7.1
Cold filter plugging point (◦C)	-	11	-
Carbon residue (% mass)	0.17	-	0.105
Water content (%)	0.02	0.098	0.036

2.1Experimental program

The engine tests were conducted at constant speed of 1500 rpm at the maximum load range. Performance parameters such as break thermal efficiency, NOx, particulate matter, smoke density, CO, HC, CO2, and O2 were measured for the following different attempts.

[i]Normal engine setup (Fuel used-diesel)at different loads.

[ii] changed the injection pressure (235,240,245 Kg/cm^2) at different loads.

[iii]Vary the injection timing (20°, 22°,24°,26°,28° BTDC) at different loads.

[iv]It is observed that the minimum value of NOx is obtained in the following Engine conditions (I.P240 kg/cm^2, I.T-24° BTDC, Max load 80%,Speed-1500 rpm)

[v] Run the Engine with Methyl Ester of Neem Oil (MENO) and its blends (B25, B50, B75 and B100) with the above said Ranges.

[vi]It was observed that the max value NOx is got on B100.

[vii]Implemented different flow rates EGR for B100 and the results are discussed.

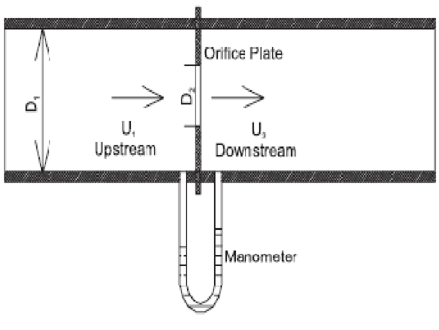


Fig. 1EGR Flow test bench

Part of the exhaust is to be recirculated and put back to the combustion chamber along with the intake air. The quantity of this EGR is to be measured and controlled accurately hence a by-pass for the exhaust gas is provided along with the manually controlled EGR vale. The exhaust gas comes out of the engine during the exhaust stroke at high pressure. It is pulsating in nature. It is desirable to remove these pulses in order to make the volumetric flow rate measurements of the recirculating gas possible. For this purpose, another smaller air box with a diaphragm is installed in the EGR route. An orifice meter is designed and installed to measure the volumetric flow rate of the EGR.

The detailed schematic line drawing of the experimental EGR system is shown in fig 1. A u-tube manometer is mounted across the orifice in order to measure the EGR flow rate. Suitable instrumentation is provided to acquire useful data from various locations. Thermocouples are provided at the intake manifold, exhaust manifold and various points along the EGR route.

The smoke density was observed by using the AVL smoke meter. The amount of particulate matter emitted was found by passing the exhaust gases through a glass filter paper placed in High volume sampler (HVAS) for time durations of one minute. The oxides of nitrogen were analysed using an exhaust gas analyser (EGA).The pressure difference across the orifice is used to calculate the EGR rate. A matrix of test conditions is used to investigate the effect of EGR on exhaust gas temperature.

III. RESULTS AND DISCUSSIONS

The engine parameters such as brake thermal efficiency (BTE), smoke density, oxides of nitrogen (NOx), particulate matter, carbon monoxide (CO), hydro carbon (HC), carbon-di-oxide (CO_2) and oxygen (O_2) are presented for various percentages of EGR Valve openings.

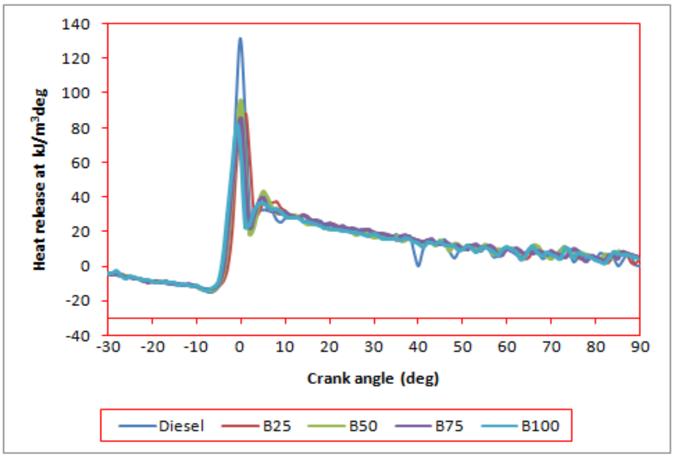


Fig. 2. Heat Release Rate curves for various fuel blends

Fig.2 shows HRR for sole and various MENO blends such as (B25-B100).It is seen that sole fuel produce more rapid increase for heat released during the initial part of the combustion whereas the blends produce slower heat release rate up to 5°TDC. Then all the blends of fuel (B25 –B100) and sole fuel (Diesel) produce same HRR. Even though the biodiesel contain Oxygen molecules, it produce lower heat release rate compared to sole fuel(diesel).This is due to the strong bonding between oxygen and other HC molecules in the Biofuel, which needs addition energy to break the bond, and hence a lower HRR. But once all the bonds are broken in Biodiesel, they show the similar Heat Release pattern as that of diesel.

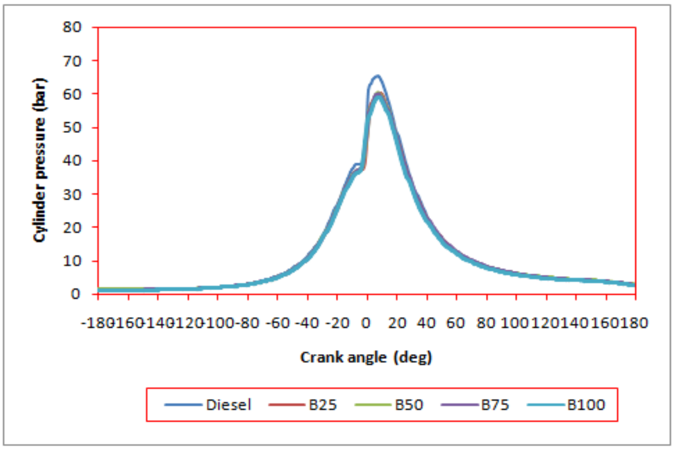


Fig.3 Temporal variation of pressure for various blends

Fig.3 shows the temporal variation of pressure for various blends of biodiesel and base fuel. This again shows a similar trend, where diesel fuel producing a higher pressure initially. The pressure produced by various blends show similar values approximately 15°TDC. This is in conformance with heat release pattern.

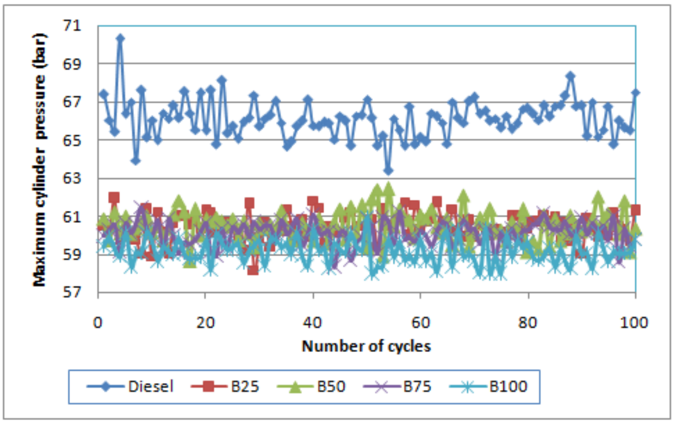


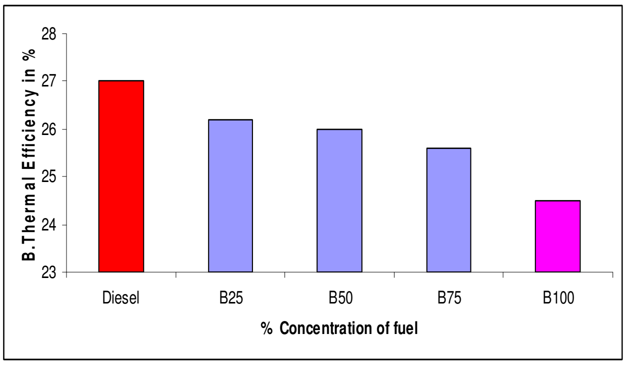
Fig 4. Cyclic variation of cylinder pressure

Fig 4 shows the cyclic variation of cylinder pressure for fuel and biodiesel blends. Hence again the cyclic variations produced by biodiesel blends are lower compared to diesel fuel.

3.1 Emission Characteristics without EGR for Diesel and Meno

3.1.1. Brake thermal efficiency

Brake Thermal efficiency (BTE) indicates the ability of the combustion system to accept the experimental fuel, and provides comparable means of assessing how efficient the energy in the fuel was converted to mechanical output. BTE results are presented in Fig. 5. It is observed that the BTE was higher for diesel fuel than blends of MENO without EGR with the same operating conditions.

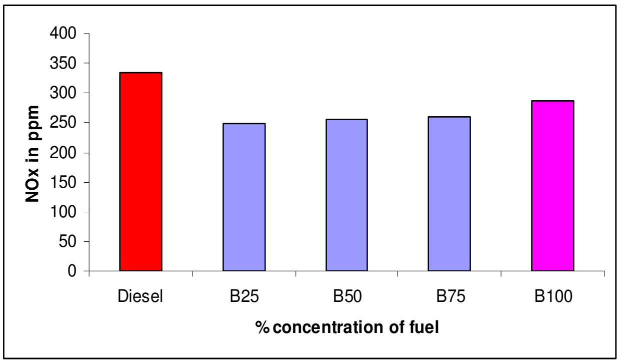


Load-80%, IP-240Kg/cm2, IT-24°BTDC

Fig. 5 Brake Thermal EfficiencyVs% concentration of fuel

3.1.2 Oxides of Nitrogen (NOx)

The most troublesome emissions from CI engines are NOx. The oxides of nitrogen in the exhaust emissions contain nitric oxide (NO) and nitrogen dioxide (NO_2). The formation of NOx is highly dependent on in-cylinder temperatures, the oxygen concentration, and residence time for the reaction to take place and. The changes in the NO emissions at different blends and sole fuel are shown in Fig. 6. It shows that the NO emissions are decreased for B 25 and maximum for B100 at low load at specified speed, injection pressure and injection timings. The significant decrease in the peak cylinder pressure is also observed for blends at this load indicating the decrease in the in-cylinder gas temperature owing to higher latent heat of vaporization of biofuel and increased ignition delay due to lower Cetane index.

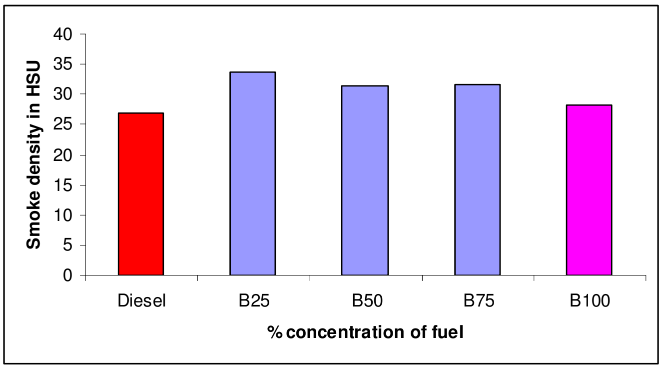


Load-80%, IP-240Kg/cm2, IT-24ºBTDC

Fig. 6 NOx Vs % concentration of fuel

3.1.3. Smoke Density

The formation of smoke is strongly dependent on engine load types of fuel used. The air fuel ratio decreases with increase in load as the fuel injected increases, resulting in higher smoke. From the Fig.7 smoke densities are higher in values for all blends of MENO than sole fuel for specified speed, injection pressure and injection timings.

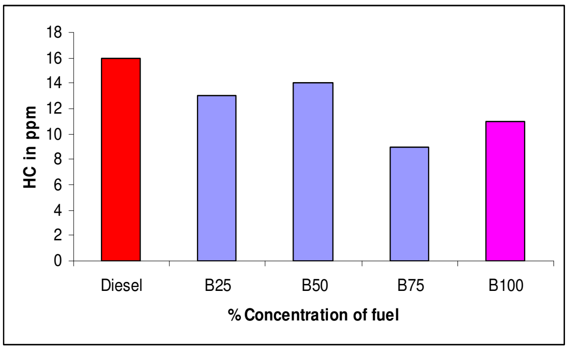


Load-80%,IP-240Kg/cm2,IT-24ºBTDC

Fig. 7 Smoke density Vs% concentration of fuel

3.1.4. Hydro Carbons (HC)

The use of bio-diesel in a conventional diesel engine results in substantial reduction of unburunt hydrocarbons. From the figure, 8 it is observed that the HC emissions are higher in values for the sole fuel. Among the blends of MENO it is maximum for B50 for the specified speed, injection pressure and injection timings.

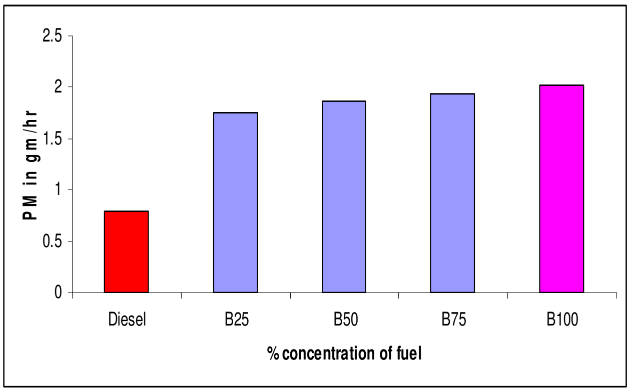


Load-80%,IP-240Kg/cm2,IT-24ºBTDC

Fig.8 HC Vs % concentration of fuel

3.1.5. Particulate Matter

The use of bio-diesel in a conventional diesel engine results in substantial reduction of CO and particulate matter. The use of bio-diesel reduces the solid carbon fraction of particulate matter (since oxygen in bio-diesel enables more complete combustion of carbon dioxide) and eliminates sulphur fractions in the fuel.



Load-80%,IP-240Kg/cm2,IT-24ºBTDC

Fig. 9 PM Vs% concentration of fuel

From Fig 9 Due to less oxygen content in MNEO the particulate emission is slightly higher in all blends of MENO for specified speed, injection pressure and injection timings.

3.2 Effects of EGR Rate on Emission Characteristics for Biodiesel (Meno)

The NOx emission is higher in all the blends of diesel- biodiesel peaking to a maximum with 100 % biodiesel fuel called B100. Hence the well proven techniqueof Exhaust gas Recirculation was implemented at different volume flow rates(25%, 50%,75%, 100% opening of EGR valve and no EGR) for the biodiesel B100 at a specified speed of 1500 rpm withan injection pressure of 240 kg/cm^2 and the injection timing(24°BTDC).

3.2.1. Brake thermal efficiency

From the Fig.10 BTE is slightly increased for blend100 and 50% EGR valve opening compared to diesel fuel at high loads of both speeds and all injection timings. This can be attributed to the rapid premixed combustion part possessed by bio-diesel blends because of improved mixing during ignition delay, oxygen enrichment, leading to higher percentage of 'constant volume' combustion and to the lower heat losses and 'leaner' combustion .

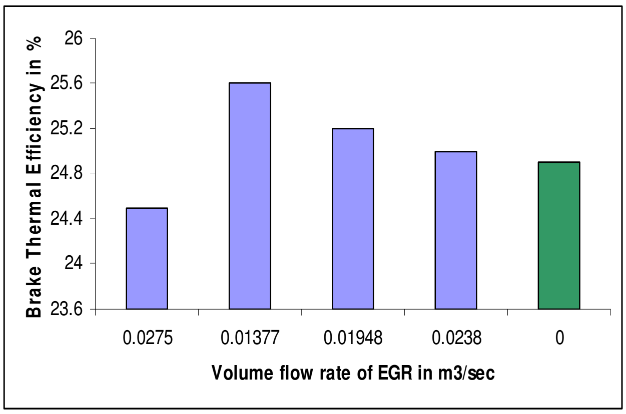


Fig 10 Brake Thermal Efficiency and various EGR Rates

The improvement of diffusive combustion phase would have also resulted due to oxygen enrichment. In addition, the total combustion duration is shortened for blends. The heat release process is almost completed at the position of same crank angle. Based on these reasons, the energy consumption rate of blends decreased and BTE increased as reported in, and However results obtained in are showing the opposite trends. This indicates that the biodiesel which is acting as a Cetane improver, kept the combustion process centered also for high bio-diesel contents blends especially at high loads.

3.2.2 Oxides of Nitrogen (NOx)

It is a well-known fact that NO formation is strongly depending on the cylinder gas temperature, residence time for the reaction, provided the excess air is available during the combustion process. From the Fig. 11 observed that the NOx values are drastically decreased at 25% EGR valve opening and more in without EGR. That is the value of NOx is reduced more than sixty percentage of the original value (without EGR).

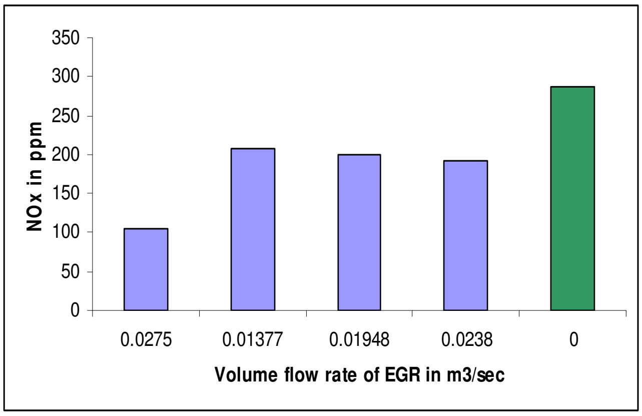


Fig 11 NOx and various EGR Rates

3.2.3. Smoke Density

The results show that the smoke is almost constant for the flow rates of EGR valve openings except 0.0275 m^3/ sec for the specified conditions for bio-diesel fuel. The formation of smoke is strongly dependent on engine load. The air fuel ratio decreases with increase in load as the fuel injected increases, resulting in higher smoke

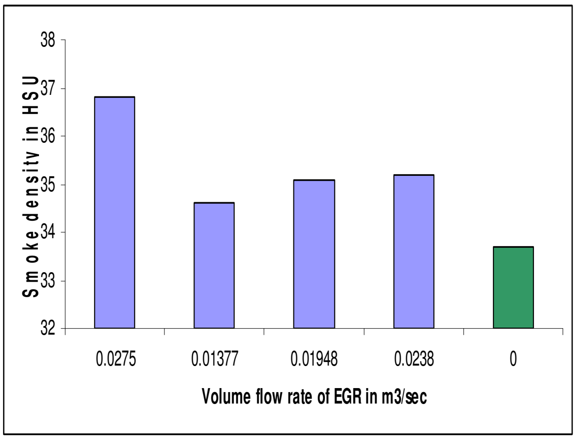


Fig 12 Smoke density and various EGR Rates

From Fig. 12 it is observed that smoke decreases for blends compared to diesel fuel, especially at high loads of all injection timings and speeds. The presence of atomic bound oxygen in ethanol satisfies positive chemical control over soot formation. The tendency to generate soot by the fuel dense region inside a blend diffusion flame sheath is reduced, due improved mixing owing to better atomization and vaporization of blends. Excessive smoke is observed for 25% EGR valve opening at the specified conditions. The heat release diagram shows that the premixed combustion is very slow and entire heat release is shifted late in the expansion stroke at these operating conditions. This would have resulted in insufficient timing for soot oxidation (exhaust valve opens before the completion of soot oxidation) and produced smoke to such a high level.

3.2.4. Hydro Carbons (HC)

The use of bio-diesel in a conventional diesel engine results in substantial reduction of unburunt hydrocarbons. From the Figure, 13 it is observed that the HC emissions are gradually decreased with increasing EGR flow rates for the specified injection pressure (240 kg/cm^2) at a speed of 1500 rpm with a constant injection timing of 20°BTDC for the bio-diesel fuel

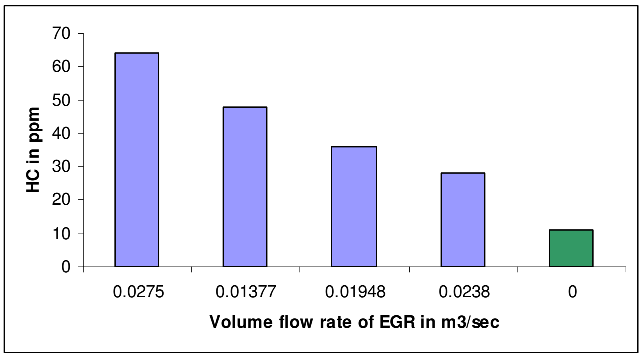


Fig. 13 HC for various EGR Rates.

3.1.5. Particulate Matter

The use of bio-diesel in a conventional diesel engine results in substantial reduction of particulate matter. The use of bio-diesel reduces the solid carbon fraction of particulate matter (since oxygen in bio-diesel enables more complete combustion of carbon dioxide) and eliminates sulphur fractions in the fuel. From the Fig.14 it observed that a slight difference in PM in different EGR flow rates. That is increase in flow rates of exhaust gas tend to reduce the PM.

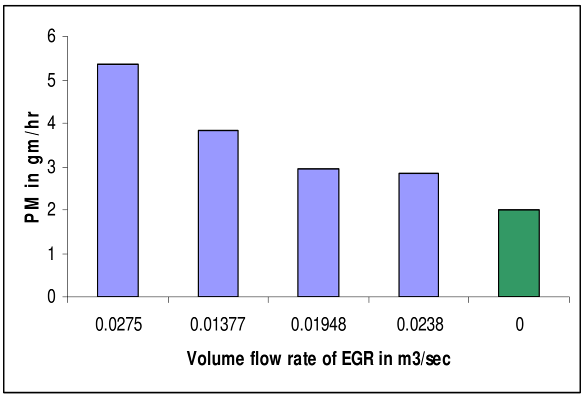


Fig 14 PM Emission for various EGR Rates

IV. CONCLUSION

The significant conclusion arrived from the experimental investigation are summarized. In this present work, maximum percentage valve opening of exhaust gas recirculation system shows reduction of NOx, CO and O_2, when compare with normal diesel engine.

- ❖ There is no appreciable change in break thermal efficiency in the implementation of the EGR.
- ❖ The NO_x level drastically decreases (approximately more than 50%) with 25 percentage EGR valve opening with the neat bio-diesel fuel for the specified conditions of Injection Pressure, Injection Timing, Speed and Load.
- ❖ Smoke and particulate matter emission level increases with 25 percentage EGR valve opening with B100 fuel(MENO).
- ❖ The Hydro carbon level decreases with adding of 25 percentage EGR valve opening to the bio-diesel fuel.

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