PERFORMANCE AND EMISSION CHARACTERISTICS OF A DIESEL ENGINE OPERATING DIESEL-BIODIESEL & BIO-ETHANOL BLEND WITH EGR

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ABSTRACT

Rapid Industrialization, increasing demand of the transport and depleting fossil fuel resources have forced the world to get an alternative solution on fuel front. Bio-fuels like alcohol and biodiesel can provide the alternative solution which is not only a green fuel it is a cheap, and renewable in nature, with a biggest limitation of producing high level of NO_X production which is confirmed in most of the studies. Exhaust gas recirculation (EGR) is an effective method to reduce NOx from biodiesel fuelled engines because it lowers the flame temperature and the oxygen concentration in the combustion chamber. However, EGR results in higher smoke opacity .The objective of current research work are to investigate the usage of biodiesel, Ethanol and EGR simultaneously in order to reduce the emissions of all regulated pollutants from diesel engine. A single cylinder, air-cooled, constant speed direct injection small capacity diesel engine was used for the experimental work. Ethanol is an oxygenated fuel and lead to smooth and efficient combustion. Atomization of ethanol results in lower combustion temperature. In this study an EGR system was developed and used for experimentation. Ethanol was added in a fixed proportion as suggested by most of the researcher in the field which is 20% the quantity and Jatropha biodiesel in the blend varied from 10, 20 up to maximum 30% and EGR was implemented from 10%, 15% and 20%. From the experimental work, it can be concluded that addition of ethanol and biodiesel along with EGR gives better performance and comparable results among all E15B20 (EGR15%) is turn out to be the best combination in most of theparameters.

Keywords :*EGR, Bio-ethanol, Bio-Diesel, Fumigation***,** *smoke opacity.*

INTRODUCTION

A comprehensive literature search reveals that so far only No experimental work is reported in the literature on the combined use of Diesel, biodiesel, fumigated ethanol with EGR. There is a definite need for more experimental data to establish the reduction of NOx emission with the use of EGR in Bio-fueled diesel engines. The current work aims to fulfill this gap by doing detailed investigations on the various aspects of using Diesel- biodiesel-Fumigated ethanol in single cylinder, direct injection diesel engine operated at different loads conditions at constant speed.

SYSTEM DEVELOPMENT AND EXPERIMENTAL SETUP

A small capacity direct injection (DI) Kirloskar Diesel engine was selected for the present study which is widely used in agriculture, small and medium scale industries for energy applications. The standard properties of the fuel used for the study are given in Table 2. The detailed technical specifications of the engine are as shown in Table 3. It was a single cylinder, naturally aspirated, four stroke, vertical, constant speed, air-cooled engine. It has a provision of loading electrically, coupled with single phase alternator through flexible coupling. Engine can be started using decompression lever provided with centrifugal speed governor. Lubrication system used in this engine was wet sump type. Inlet and exhaust valve operated with the help of an overhead camshaft driven from the crankshaft through two pairs of bevel gears. Fuel pump is driven from the end of camshaft. Air box with dimensions 630_405_175 (in mm), made of mild steel was used to measure mass flow rate of air. Orifice size of box was 35 mm for using with carburetor and inlet manifold simultaneously; it was fitted with two outlets with one end connected to carburetor and other to the main engine inlet. A control system for controlling of throttle valve of Likuni make (Japan), 125 cc bike CV (constant velocity) carburetor is as shown inFig.1. With full closing and full opening of throttle, it was possible to vary ethanol mixing from 3 to 48 percent. In conventional carburetors, throttle cable is connected directly to the throttle slide and when throttle is changed, the slide lifts and immediately increases the size of the carburetor opening letting in more air/fuel mix and increasing the speed of the engine. In CV carburetors, throttle cable actuates a butterfly valve, and as the throttle open, air pressure difference between the sealed chamber above the vacuum slide and inside carburetor venturi forces the slide (located in front of the butterfly valve) up and down. The downside of CV carburetors lack immediate throttle response. Change in the throttle gives relatively leisurely acceleration compared to a conventional carburetor. In the float chamber, the main jet controls the amount of fuel sent to a tube called the needle jet. Needle jet opens into the main bore of the carburetor and allows the fuel into the intake manifold by means of the negative pressure formed by the intake air rushing through the venturi. Piston carries the _jet needle' that fits into the needle jet. Jet needle was straight for about 1/3 of its length; the rest was tapered. At idle and low speeds, piston was nearly all the way down, pushing the needle into the needle jet most of the way. In this position, the straight, large-diameter part of the needle (the root) fills up most of the space inside the needle jet tube, restricting the fuel flow to a narrow annular space around the needle. As the piston rises with increased engine speed, the needle withdraws from the jet. The needle was tapered, therefore the annular space through which the fuel can travel increases and allow more fuel to match the increased airflow. For the exhaust gas recirculation exhaust gas is 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 valve. 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 recalculating gas possible. For this purpose, another smaller air box is installed in the EGR route. An orifice meter is designed and installed to measure the volumetric flow rate of the EGR. A U-tube manometer is mounted across the orifice in order to measure the EGR flowrate.

EXPERIMENTAL SETUP AND TESTING PARAMETERS

Fuel measurementwas done with the help of two burettes of size 50ml. One was used for ethanol and the other for Diesel fuel. One end of burette was connected to stop the valve the other was connected

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to carburetor and engine fuel filter. Proximity rpm sensor was used to measure the speed. Two separate fuel tanks are used for Diesel and ethanol. The capacity of Diesel fuel tank was 10 L whereas for ethanol it was 2 L. Both tanks were connected to burette. Fuel from valve enters into the engine through fuel measuring unit, which enables the volumetric flow of the fuel to be measured easily Smoke opacity was measured using AVL 437 smoke meter and AVL Di gas analyzer was used to measure CO2, CO, NOx and unburned HC. All instruments and the methods selectedwere of standard quality and the error was with in the permissible range. A typical pressure and crank angle Diagram of the test engine under working condition is shown in Fig.2. The schematic diagram of the experimental setup with a carburetor, along with all instrumentation, is shown in Fig.3. The engine loading was changed by varying the load on the engine alternator. A series of incandescent bulbs (200 Wand 100 W) was used to load the alternator with suitable on or off switches so that the required loading of the engine can be carried. K type thermocouples were used to measure the temperature at the salient point of the test rig. Voltage and current generated by the alternator were measured by using ammeter and voltmeter which were fixed in the controlpanel.

Experimental procedure

Initially engine is tested on the pure diesel and 30 minute time is given for steady condition. In a particular load condition, emission measurement is taken out and reading is noted. First reading is noted at no Load then 20%, 45%, 70% and 100% all the load readings are noted down. There are series of the precautions that are taken care off while performing the diesel engine test run. Reading were taken when the engine come into steady state. Digital RPM sensor and indicator were used though it was constant speed diesel engine in order to check the variation in speed from no load to full load and its effect on various other parameters.

Load was varied by changing the power output from the alternator side which was connected to the load bank. Digital ammeter, voltmeter were used for getting the readings. Optimization of the diesel engine hardware is necessary to avoid leakage of energy to obtain the result with beat of accuracy.

Subsequent reading for various blends of Diesel and biodiesel with constant addition of Ethanol by method of Fumigation and varying EGR were obtained and compared.

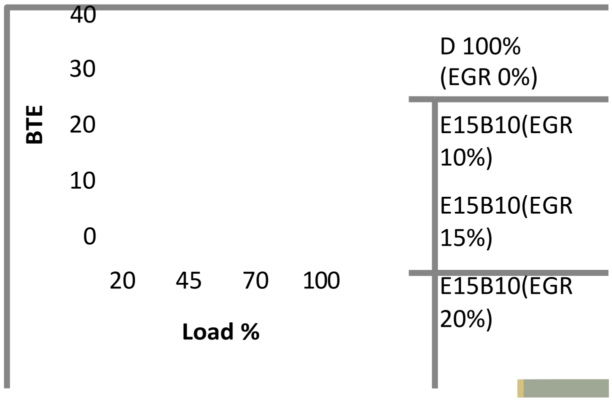
PERFORMANCE CHARACTERISTICS

The result of the series of tests conducted on engine with Jatropha Biodiesel, Ethanol with different EGR rates are summarized as follows.

Brake Thermal Efficiency

Fig .1 and 2 shows the comparison of BTE of pure diesel and all other combination of fuel with different EGR rate. Comparable values of efficiency were obtained for all combinations.

Chapter 3
ExperimentalSetup



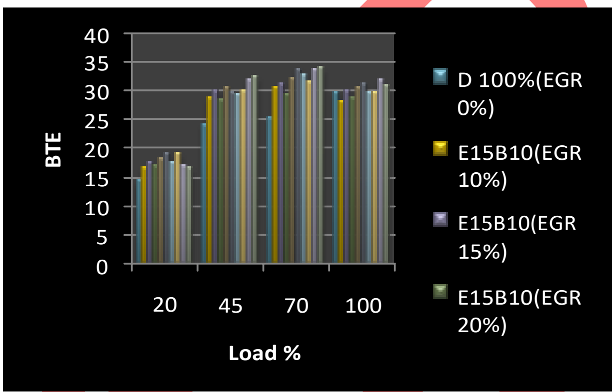


Figure1 BTE v/s Load **Figure 2 BTE v/s Load (Bar Chart)**

The biodiesel based fuels have shown small improvement in thermal efficiency due to the increased combustion velocity because of higher intake change temperature with EGR. Hot EGR is found to have resulted in improved combustion due to higher inlet temperature. In addition it may also be possible that EGR being at slightly higher temperature than atmosphere might have reduced pumping losses also. The chemical effect of EGR associated with dissociation of carbon dioxide to form free radical can also be attributed to this improvement in efficiency. It is also observed that BTE at higher rate was less than with lower EGR rate at peak loads; the drop in efficiency at higher level is probably due to predominant dilution effect of EGR leaving more exhaust gases in combustion chamber. At 45% and 70% load the combination of E15B20 (EGR15%) gives higher BTE.

Brake Specific Fuel Consumption: Fig 3 and 4 shows variation of brake specific fuel consumption BSFC with respect to load. Brake power depends on the engine design and type of fuel used, Fuel pump of the engine deliver fuel in volumetric basis. As the density of Jatropha is higher than diesel, the plunger in the fuel injection pump discharge more biodiesel compared to that of diesel. Therefore BSFC is comparable with that of diesel.

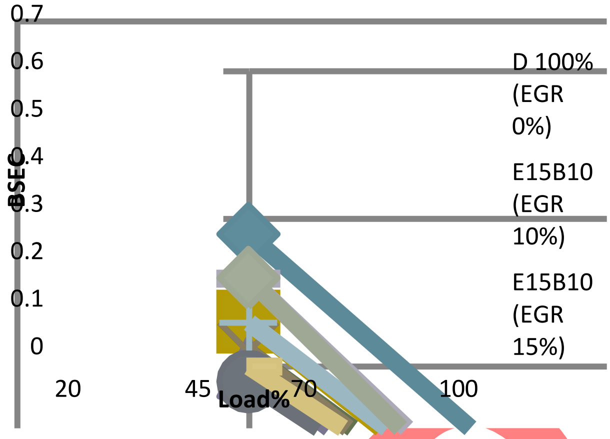


Figure 3 BSFC v/s Load

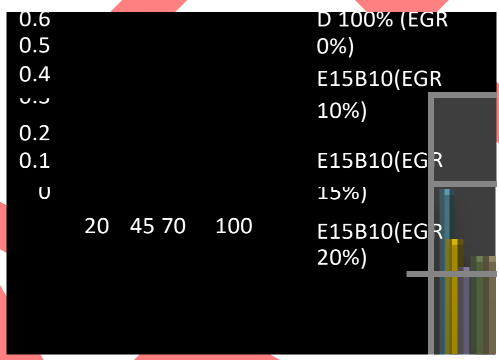


Figure 4 BSFC v/s Load (Bar Chart)

The plot of BSFC is similar to an inverse plot of BTE which is explained by the fact that reduction in brake thermal efficiency will invariably increase fuel consumption to meet the same load requirement. It was observed that BSFC at 15% EGR rate was higher than 20% at lower rate. At 45% and 70% load, the combination of E15B20 (EGR15%) has least value ofBSFC.

Emission Characteristics

NO_x emissions: The variation of NO_x emission for all test fuel is shown in fig. 5 and 6 The NO_x emissions increased with the increasing engine load, due to higher combustion temperature. This proves that the most important factor for the emission of NO_x is the combustion temperature in the engine cylinder and the local stoichiometry of the mixture.

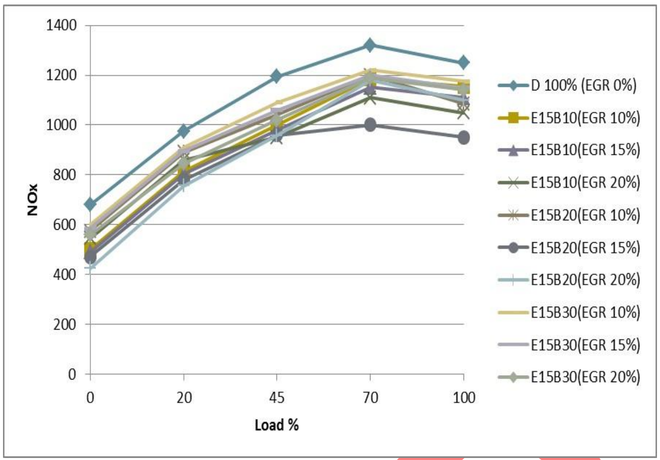


Figure 5 NO_x v/s. Load

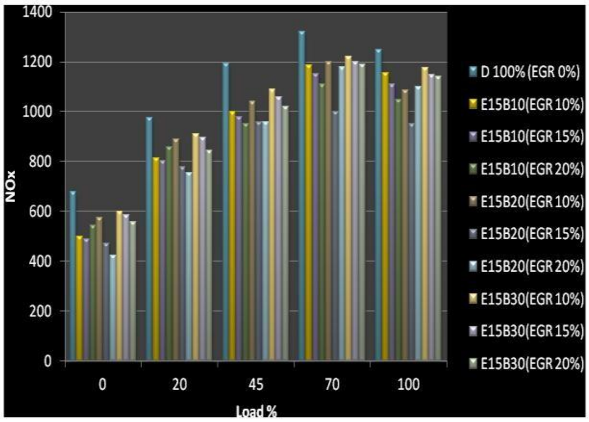


Figure 6 NO_x v/s Load (Bar Chart)

NO_x emissions were higher for biodiesel and ethanol fuel as compared to diesel. This is probably due to higher bulk modulus of biodiesel resulting in a dynamic injection advance apart from static injection advance provided for optimum efficiency. Excess oxygen (10%) present in the biodiesel and ethanol would have aggravated the situation. At higher loads NO_x levels were higher. The graph shows the well established benefit of EGR in reducing NO_x emissions from diesel engine. The degree of reduction of NO_x at higher loads is higher. The reason for reduction in NO_x emission using EGR in diesel engine is reduced oxygen concentration and decreased flame temperature. However, NO_x emission in case of bio fuel are higher than diesel due to higher temperature prevalent in the combustion chamber which is to some extent counter balanced by higher latent heat of evaporation ofethanol.

Hence, it is observed that E15B20 (EGR15%) reduces the maximum emission of NO_x. This is increased in case of B30 as availability of oxygen is increased and EGR20 where the temperature of air in the combustion chamber is increased.

Carbon Monoxide Emission: In this experiment CO and HC emission are measured to check the completeness of combustion inside the cylinder. Fig no 7 and 8 compare the CO emission for the set of fuel with different EGR rate for all load condition and compared with diesel baseline data. At full load steep rise in CO emission is probable due to the dilute effect of exhaust gases and lower air fuel ratio.

It is observed that diesel and E15B10 (EGR 20%) gives maximum of CO emission which is probably due to oxygen deficient operation. Here it is important to note that with 15% and more EGR rates combustion quality detoriatesfaster.

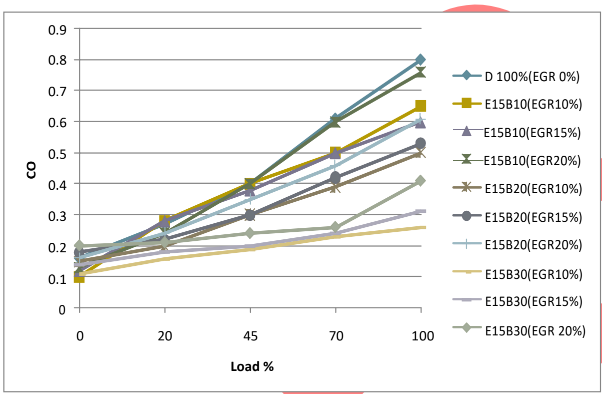


Figure7. CO v/s Load

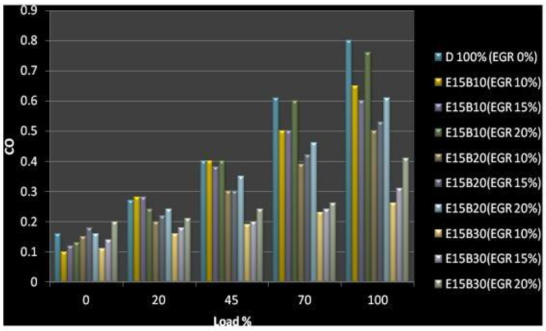


Figure 8. CO v/s Load (Bar Chart)

Above figure compares CO emission of various fuel combinations with different EGR rate with baseline diesel data. The CO emission from the pure diesel fuel is higher than from bio fuels. This is possible because of the molecule oxygen capability in biodiesel and ethanol. With increasing with EGR percentage, the emission remains same at lower loads but increases at higher loads due to dilution effect of exhaust gases. At all loads E15B30 (EGR 10%) minimises CO emission, But CO emission for E15B20 (EGR 15%) is comparable. As oxygen present in bio-fuels convert CO into CO_2 and higher values of CO at higher percentage of EGR due to removal of oxygen from the charge.

Un-burnt Hydro carbon emissions: Effect of EGR, ethanol and biodiesel on UBHC are shown in fig.9 and 10. These graph shows that HC emissions increases with increased EGR percentage and load. The HC emissions of all the fuel combination are lower in partial engine load but increases at higher engine load. The possible reason may be lower excess oxygen available for combustion. Lower excess oxygen concentration results in poor fuel mixture at different location inside the combustion chamber. The heterogeneous mixture does not combust properly and results in higher HC emissions. Adding bio-fuels to diesel decreases the oxygen requirement for combustion because of presence of molecular oxygen in fuel. This results in lower HCemission.

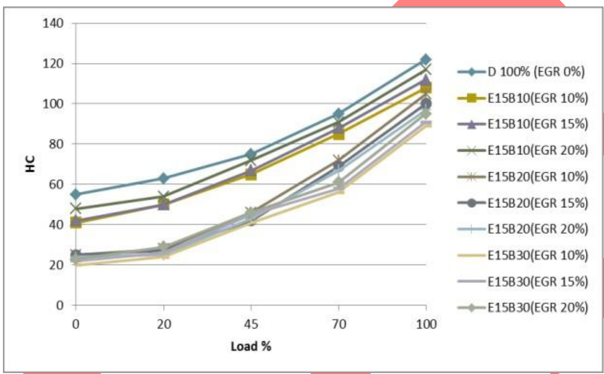


Figure 9. HC v/s Load

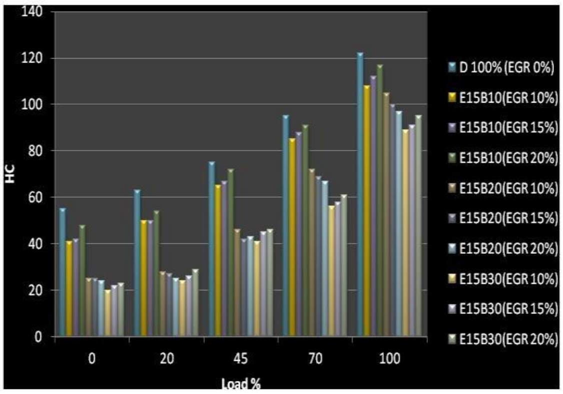


Figure 10. HC v/s Load (Bar Chart)

Fig shows application of EGR shows slight reduction in HC emission than without EGR. The trend followed up to 15% EGR rate. This is due to reburning of HC's in combustion chamber. Beyond 15% EGR every addition of EGR rate decreases oxygen availability in the chamber for combustion of fuel at all loads. E15B30 (EGR10%) minimize HC emissions but HC emission for E15B20 (EGR15%) iscomparable.

Smoke Opacity: Fig 11 & 12 shows the comparison of smoke opacity with baseline diesel data for all set of test fuels at different load condition for various EGR rate. Higher smoke opacity of the exhaust is observed when the engine is operated with higher EGR rate.EGR reduces availability of oxygen for combustion of fuel, which result in incomplete combustion and increased formation of PM. Smoke opacity for biodiesel blends with EGR is noticed to be generally lower than that of diesel. The molecule of biodiesel contain some oxygen that takes part in combustion and this may be a possible reason for improved combustion and thus lower smoke.

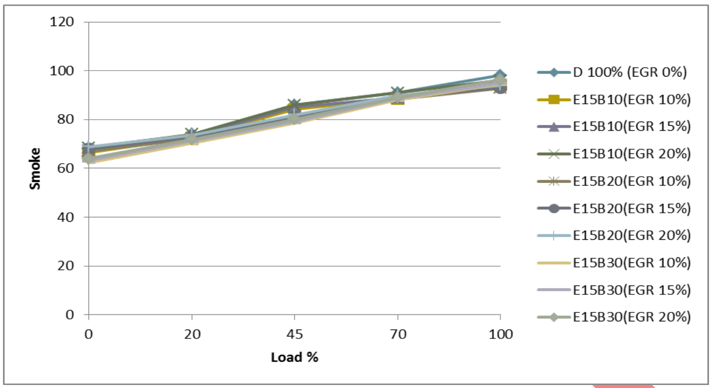


Figure11. Smoke v/s Load

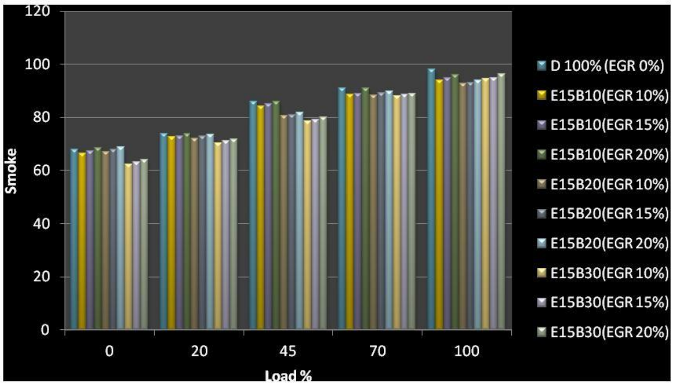


Figure 12. Smoke vs Load (BarChart)

Within the experimental range, the smoke opacity for diesel is lower than diesel fuel for no load to full load condition. This may be due to the fact that molecular oxygen content of biodiesel may be responsible for better combustion and result into lower smoke opacity. Opacity increases with increase in EGR rate for no load to full load. In case of bio fuels sudden rise in particulate matter is observed with 20%EGR. E15B30 (EGR10%) exhibits the minimum smoke but E15B20 (EGR15%) results are also comparable.

CO_2 Emission: The CO_2 emission is shown in fig.13 & 14 The CO_2 emission increases with increase in the engine load. The CO_2 emission with E15B20 was greater than the base line diesel. However, with increase in EGR rates the CO_2 emission decreased. Lesser amount of CO_2 in exhaust emission is an indicator of the incomplete combustion of the fuel. This supportthe lower value of exhaust gas temperature. The combustion of fossil fuels produces carbon dioxide which is getting accumulated in atmosphere and leads to many environmental problems.

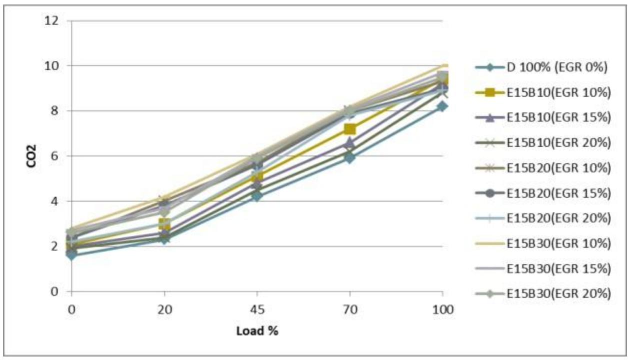


Figure 13. CO_2 v/s Load

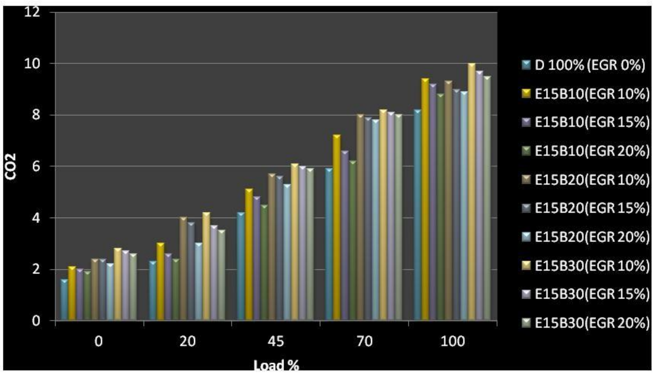


Figure 14. CO_2 v/s Load (Bar Chart)

The combustion of bio fuels also produces carbon dioxide but crops are readily absorbing these and hence carbon dioxide levels are kept in balance. Thus considering the closed cycle of biodiesel it can also be pointed out that the effective emission of CO_2 is relatively lower.

CONCLUSION

The engine performance and exhaust emission characteristics of Jatropha biodiesel with blended ethanol and diesel fuel with implementation of EGR were experimentally investigated in a single cylinder 4 stroke unmodified engine under laboratory test condition. Firstly performance and emission tests were made in order to determine the base performance and emission values of the engine with only diesel and to be able to compare to understand the effect of Blending Jatropha biodiesel, ethanol and implementing EGR. Ethanol was added in a fixed proportion as suggested by most of the researcher in the field which is 20% the quantity and Jatropha biodiesel in the blend varied from 10, 20 up to maximum 30% and EGR was implemented from 10%, 15% and 20%.

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