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Experimental Investigation on effect of EGR on Performance and Emission Characteristics of Biodiesel (Karanja) Fueled Engine

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Abstract—**Transtesterified fuels (biodiesel) from vegetable oils are alternative fuels for diesel engines. However several studies reported that diesel engine fueled with bio-diesel emits more NOx emissions. To meet diesel vehicular exhaust emission norms worldwide, several exhaust pretreatment and post treatment technique have been employed in diesel engine. This project aims at experimental investigation on effect of EGR in performance and emission characteristics of a diesel engine fueled with biodiesel. The performance and emission parameters were studied with different EGR valve opening 5%, 10% and 15% respectively. The results shows that, engine emits NOx when fueled with bio-diesel (without EGR). It is due to long hydrocarbon chain and lack of oxygen content. With increase in EGR flow rates; there will be reduction in NOx was observed. But hydrocarbon emission, CO, CO2 were increased slightly at high loads. Whereas there is no major variation in brake thermal efficiency was observed.**

Index terms - diesel engines, biodiesel, EGR, emission.

I. INTRODUCTION

Economic growth of a country is very much dependent on the long term availability of energy. The sources of energy should be safe and environment friendly. Diesel engine is preferred prime movers for power generation due to its excellent drivability and higher thermal efficiency. Despite their advantages they produce higher levels of NOx and smoke emissions which have significant effect on human, animal, plant, and environmental health and welfare. In order to meet the emission norms and also the depletion of petro diesel oil reserves lead to the research for alternative fuels for diesel engines. Biodiesel from vegetable oils are alternative to diesel fuel for diesel engines. The use of biodiesel in diesel engines does not require any engine modification. An important property of biodiesel is its oxygen content which is usually not contained in diesel fuel. Biodiesel gives considerably lower emissions of PM, carbon monoxide (CO) and hydrocarbon (HC) without any fuel consumption or engine performance penalties. Exhaust gas recirculation (EGR) can be used with biodiesel in the diesel engines. EGR is an effective technique of reducing NOx emissions from the diesel engine exhaust.

Ladommatos et al. (1998) tested the effect of exhaust gas recirculation on diesel engine emissions. They noticed a large reduction in NOx emissions at the expense of higher particulate and un-burnt hydrocarbon emissions. [1]. D.Agarwal (2006) suggested that controlling the NOx emissions primarily requires reduction of in-cylinder temperatures. [2]. Y. Yoshimoto (1999) reported that the application of EGR results in higher fuel consumption and emission penalties, also EGR increases HC, CO, and PM emissions along with slightly higher specific fuel consumption. [3]. Yokomura et al. (1994) have suggested that exhaust gas recirculation is one of the most effective ways for nitrogen oxides (NOx) reduction process. [4]. Zheng, G. T. Reader (2004) et al. have studied the effect of EGR on NOx emission and reported that the EGR rates are sufficient for high load, also as the load increases; Diesel engines tend to generate more smoke because of reduced oxygen. Therefore, EGR, although effective to reduce NOx, further increases the smoke and PM emissions. [5].

A.K. Agrawal et al. (2004) reported that in diesel engines NOx formation is very much depended upon temperature. To reduce NOx emission in the exhaust of a diesel engine, it is necessary to keep combustion temperature under control. [6]. Santoh et al. (1997) done an experiment on a naturally aspirated single cylinder DI diesel engine with various combinations of EGR, fuel injection pressures, injection timing and intake gas temperatures affect exhaust emissions and they found that NOx reduction ratio has a strong correlation with oxygen concentration regardless of injection pressure or timing. EGR lowers the average combustion temperature and reduces the oxygen intake gases that adversely affect the smoke emission and soot formation.

They also suggested that for a given level of oxygen concentration the cooled EGR reduces more NOx with less EGR rates than does at hot EGR [7]. Abu-Jrai et al, (2007) have analyzed the effect of exhaust gas recirculation (EGR) on pollutant emission in diesel engine. [8].

Saravanan et al. (2008) performed a series of test on a single cylinder water cooled DI diesel engine with hydrogen was used as dual fuel mode with EGR technique. They reported increase in brake thermal efficiency and lowered smoke level, particulate and NOx emissions due to absence of carbon in hydrogen fuel. [9]. Hountalas et al. (2008) have presented 3D-multi dimensional model to examine the effect of EGR temperature on a turbocharged DI diesel engine with three different engine speeds.

They reported that high EGR temperature affects the engine brake thermal efficiency, peak combustion pressure, air fuel ratio and also soot emissions, and the combined effect of increased temperature and decreased O2 concentration resulted low NOx emissions. Also they suggested that EGR cooling is necessary to retain the low NOx emissions and prevent rising of soot emissions without affecting the engine efficiency at high EGR rates. [10].

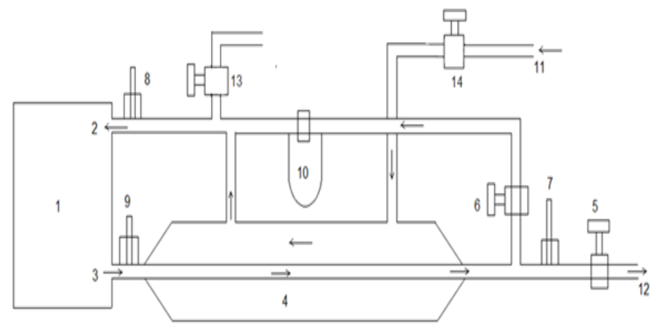
Abd-Alla et al. (2001) have done experiments on a dual fuel (gaseous fuel- methane with diesel as pilot fuel) mode direct injection diesel engine to study the effect of inlet air temperature by the way of mixing of hot EGR and addition of diluents gas such as CO2 and N2 They observed that the addition of CO2 gas in the intake charge increased un-burnt hydrocarbon emission (UBHC) but moderate reduction of NOx emission. By increasing the intake charge temperature NOx emission was increase with decrease in UBHC. The brake thermal efficiency and power output increased due to reduced ignition delay. Also they suggested that the performance was improved at low load condition when the intake air temperature was increased. The main objective of the present work is to investigate the effect of EGR on performance and emission characteristics of biodiesel fueled engine.

II. EXHAUST GAS RECIRCULATION

In exhaust gas recirculation process, a fraction of the engine out exhaust gas is re-circulated to the engine. Oxides of nitrogen are formed when the temperature inside the combustion chamber exceeds the critical temperature so that the molecules of nitrogen and oxygen combine [4]. Inter-mixing the incoming air with re-circulated exhaust gas basically cuts off some percentage of the oxygen going into the combustion chamber and lowers the adiabatic flame temperature. The exhaust gas increases the specific heat of the mixture and lowers the peak combustion temperature. NOx formation progresses faster at higher temperatures. EGR serves to limit the formation of NOx. There is no doubt that EGR is very effective in reducing oxides of nitrogen, but it also has adverse effects on the engine efficiency. As it contains a lot of particulate matter, it may also contaminate the lubricating oil and can also foul the intake manifold.

III. EXPERIMENTAL SETUP

An experimental investigation was carried out to investigate the influence of exhaust gas recirculation on the performance and exhaust emission of a diesel engine. The engine used for the investigation was computerized single-cylinder, four-stroke, and water cooled diesel engine with eddy current dynamometer. The technical specifications of the engine are given in Table I, and the schematic of the experimental setup is shown in Figure 1. The power output of the engine was measured by an electrical dynamometer. AVL gas analyzers was used for the measurement of amounts of exhaust emissions. For smoke opacity measurement AVL smoke meter was used. Rota meters were used to measure the volume flow rates of inlet charge as well as exhaust gas to be re-circulated. Digital control panel was used to collect data such as torque, water flow of engine etc. A known quantity of exhaust gas with air was re-circulated into the combustion chamber and was performed with manually controlled EGR valve.



1-single cylinder diesel engine 7,8,9-thermometer
2- inlet valve 10-u tube manometer
3-exhaust valve 11-fresh air inlet
4-heat exchanger 12-exhaust outlet
5,6-exhaust control valve 13,14-inlet control valve

Figure 1. Experimental setup

Parameters	Specifications
Make	Kirloskor-AV1
Type	Vertical ,water cooled
Speed	1500 rpm
Brake power	5.2 kW
Bore	87.5 mm
Stroke	110 mm
Loading arrangement	Mechanical type
EGR	Variable valve opening, Hot EGR

Table 1. Engine Specifications

PROPERTY	UNIT	VALUE
Chemical formula (Methyl Linoleate)		$C_{19}H_{34}O_2$
Density	gm/cc	0.924
Calorific Value	MJ/kg	41
Fire point	°C	230
Flash point	°C	235
Specific gravity		0.876
Viscosity	mm2/sec	5.5
Cetane number		39

Table 2.Properties of Biodiesel

IV. CALCULATION OF EGR RATE

When the impact of EGR on the emissions is assessed, it is essential to know the EGR ratio

$$\%EGR = \frac{\text{Mass of EGR}}{\text{Mass of total intake mixture into the cylinder}} \times 100$$

Another way to define the EGR ratio is by the use of CO2 concentration

$$\text{EGR ratio} = \frac{[CO_2]\text{ intake} - [CO_2]\text{ ambient}}{[CO_2]\text{ exhaust} - [CO_2]\text{ ambient}} \times 100$$

V. RESULTS AND DISCUSSIONS

The experiment was carried out in a four stroke single cylinder, water cooled diesel engine using Diesel, Karanja 50+Diesel50 and Karanja Biodiesel at 1500 rpm and different EGR rates. The effect of EGR on the performance of the engine like brake thermal efficiency and specific fuel consumption and emission characteristics like HC,CO emission and NOx concentration in the tail pipe emissions. 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. Using biodiesel in diesel engine, smoke is decreased with increase in NOx. Thus, biodiesel with EGR can be used to reduce NOx.

5.1. Brake thermal efficiency

Figure 2 shows the variations of brake thermal efficiency with brake power for Diesel, Karanja50+Diesel50 and Karanja Biodiesel respectively with and without EGR at constant speed of the engine. It is observed from the figures that the brake thermal efficiencies are increased with increase in load with or without EGR at lower load. This is due to re-burning of hydrocarbons that enter in to the combustion chamber during suction with the re-circulated exhaust gases. The brake thermal efficiency of diesel fuel is higher than Karanja biodiesel at all loading conditions with and without EGR operations due to its higher heating value of diesel. At full load condition the brake thermal efficiency marginally decrease.

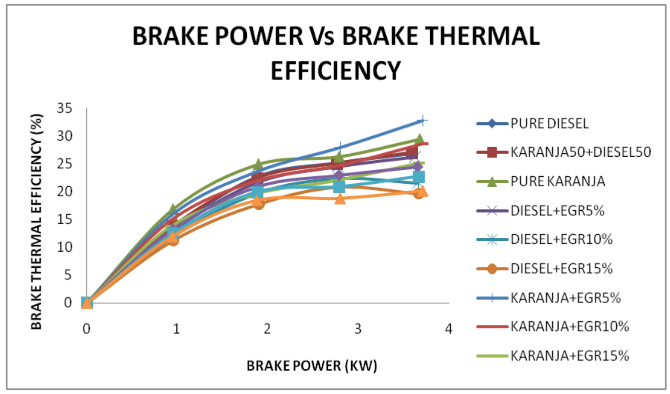


Figure 2. variation of break thermal efficiency with brake power

5.2. Specific fuel consumption

Figure 3 shows the variations of SFC with brake power for Diesel, Karanja 50+Diesel50 and Karanja Biodiesel respectively with and without EGR at constant speed of the engine. The specific fuel consumptions are lower for diesel at all loading conditions when operated with EGR and without EGR when compared to Karanja biodiesel. So, for Karanja more mixtures are required for constant power output. However, at higher loads of the engine, SFC with 10% EGR is almost same to that of without EGR for diesel fuel but 8.8% higher at full load operation for Karanja with 10% EGR.

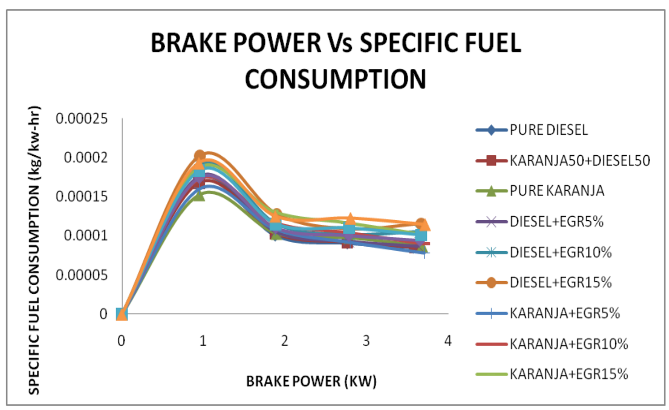


Figure 3. variation of specific fuel consumption with brake power

5.3. Oxides of nitrogen emission (NOx)

Figure 3 shows the variations of NOx emissions with brake power for Diesel, Karanja 50+Diesel50 and Karanja Biodiesel respectively with and without EGR at constant speed of the engine. It is observed from the figure that the bio-diesel emits higher NOx than diesel fuel at all loading conditions due to higher oxygen content of bio-diesel provide high local temperature and complete combustion of the bio-diesel.

The emission of NOx tends to decrease significantly with the increase of EGR rate for all loading conditions for diesel and karanja biodiesel the fuels due to reduction of oxygen concentration for the presence of inert gases such as CO2 and H2O in the cylinder that decreased the flame temperatures in the combustion chamber. At full load condition NOx emission for diesel and karanja biodiesel are respectively 612ppm, 782ppm and 923ppm at constant speed of the engine without EGR. From the figure it is observed that maximum NOx reduction occurs with 10% EGR. At full load condition reduction of NOx for SOME and diesel was respectively 146ppm, 167ppm and 180ppm with 10% EGR.

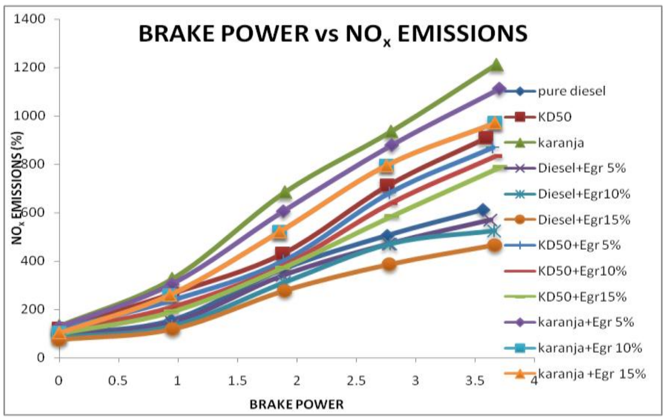


Figure 4. Variation of NOx emission with brake power

5.4 Hydrocarbon emission (HC)

Figure 5 shows the variations of hydrocarbon (HC) emissions with brake power for Diesel, Karanja 50+Diesel50 and Karanja Biodiesel respectively with and without EGR at constant speed of the engine. From the figure it is observed that hydrocarbon emission increases with the increase with load in the engine due to insufficient amount of oxygen in the combustion chamber resulting incomplete combustion. Due to presence of molecules of oxygen in KD50 emits lower HC than diesel fuel. At full load condition karanja biodiesel +EGR10% HC than diesel when operated without EGR and with10% EGR.

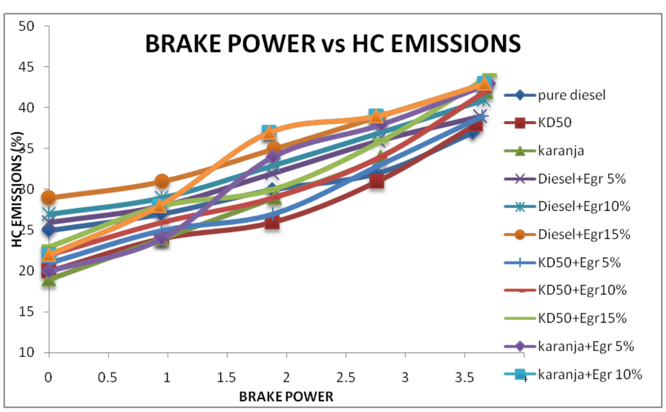


Figure 5. Variation of HC emission with brake power

5.5 Carbon monoxide Emission(CO)

Figure 6 shows the variations of Carbon monoxide (CO) emissions with brake power for Diesel, Karanja 50+Diesel50 and Karanja Biodiesel respectively with and without EGR at constant speed of the engine. The CO increases with increase in load and EGR rate. However, CO emissions of SFME were comparatively lower. Higher values of CO were observed at full load for both diesel and biodiesel fuels with EGR. For biodiesel, the excess oxygen content is believed to have partially compensated for the oxygen deficient operation under EGR. Dissociation CO2 to CO at peak loads where high combustion temperatures and comparatively fuel rich operation exists, can also contribute to higher CO emissions.

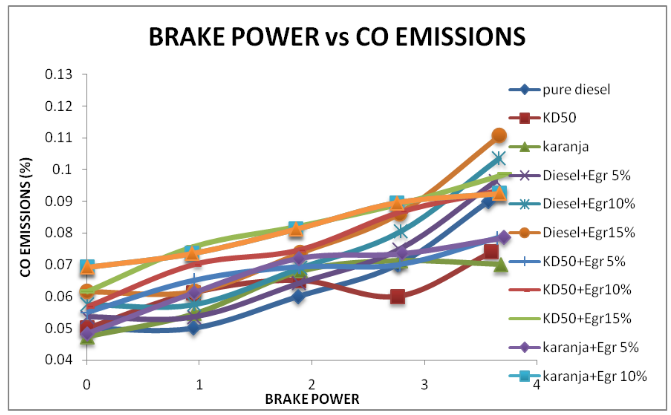


Figure 6. variation of CO emission with brake power

VI. CONCLUSION

An experimental investigation was carried out on a single cylinder four stroke, water cooled diesel engine operated on Diesel, KD 50 and Karanja biodiesel with and without exhaust gas recirculation. The effect of EGR on the performance and exhaust emissions of the diesel engine were analyzed. The results of this study may be concluded as follows:

1. When the engine was operated with Karanja+Diesel, the brake thermal efficiency decreases due to the lower calorific value of biodiesel compared to net diesel fuel. The brake thermal efficiency increases at low EGR rates for these fuels. However, increasing EGR flow rates to high levels resulted in decrease in brake thermal efficiency for both net diesel fuel and Karanja.

2. It is observed from the figure that the bio-diesel emits higher NOx than diesel fuel at all loading conditions. The NOx emissions were decreased with increase in EGR flow rate for both net diesel fuel and Karanja biodiesel.

3. The emissions of HC were found to be lower with Karanja biodiesel. However, with the increase of EGR flow rates resulted in considerable rise in HC emissions.

4. The specific fuel consumption for Karanja+Diesel KD50 was slightly higher than diesel fuel at all loading conditions when operated with and without EGR.

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