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"Experimental Investigation of Reformed EGR (REGR) on the Performance and Emission of 4 stroke C.I. Engine with palm bio-fuel"

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Abstract— Rapid increase in energy demand, constant increment in fuel utilization and exhaustion of non-renewable energy sources has emerged an escalated scan for bio diesel as an elective fuel for diesel engine. Diesel fuelled CI Engine is a widely accepted prime mover owing to its high fuel conversion and load bearing capabilities. However, its use is constrained by high NOx and PM emission. To address the issue of effective abatement of these emission, an attempt will be made in the present work and experimental studies on the effect of reformed EGR of a single cylinder 4 stroke CI engine with palm biofuel. So, we are trying to reduce drawback of conventional EGR.

Keywords—EGR, REGR, Performance and Emission Characteristics.

I. INTRODUCTION

Internal Combustion (IC) engines play a vital role of prime movers in the area of power, propulsion and energy. In recent years, with increase in automotive propulsion and industrialisation, fossil fuel prices have hiked due to limited petroleum resources. Pollutants emitted by IC engines are causing negative impacts to flora and fauna. Between Spark Ignition (SI) and Compression Ignition (CI) engines, CI engines are considered to be superior power horses for on-road heavy, medium vehicles, off-road power generation and marine application. There is a growing market for share of CI engines due to good engine performance, reliability, durability, better fuel consumption and lower exhaust emissions of hydrocarbon, carbon monoxide, and carbon dioxide when compared to SI engines. However, CI engines suffer from combustion noise, high NOx emissions, vibration and smoke emissions compared to SI engine. Reduction of both NOx and PM emissions simultaneously is quite difficult task because at high temperatures inside the combustion chamber it promotes the soot oxidation thereby reducing particulates but favouring the NOx formation environment. At the same time lower temperature inside the CC leads to soot formation. So two tracks of research EGR and hydrogen addition to reduce emissions are combined together and came with new technique REFORMED EGR (REGR).

II. PALM BIO-DIESEL PRODUCTION

Transesterification reaction is a stage of converting oil or fat into methyl or ethyl esters of oily acid, which constitutes to biodiesel. Biodiesel (methyl ester) is obtained through the response of triglycerides of vegetable oils with an active intermediary, formed by the response of an alcohol with a catalyst. The common reaction for obtaining biodiesel through transesterification is:

Oil or Fat + ***Methanol*** → ***Methyl Esters*** + ***Glycerol***

Or

Oil or Fat + ***Ethanol*** → ***Ethyl Esters*** + ***Glycerol***

The production of biodiesel by transesterification of vegetable oil uses the following steps:

1. Mixing of alcohol and catalyst: Potassium hydroxide (KOH) and sodium hydroxide (NaOH) are generally used as alkaline catalysts with methanol (CH_3OH) for production of biodiesel.

2. Reaction: The alcohol/catalyst mix is charged into a closed reaction vessel and the vegetable oil is added. The reaction mixture is heated to the boiling temperature of the alcohol (normally 50 to 60 °C) and is refluxed for a certain length of time under agitation. The reaction mixture has a conversion efficiency of 96% to 99% in relatively short times (around 60 minutes). When agitation is stopped the reaction mixture separates into an upper layer of methyl esters and a lower layer of glycerol diluted with un-reacted methanol.

3. Separation of glycerine and biodiesel: Once the reaction is complete, two major products are produced: glycerine and biodiesel (methyl ester). The quantity of produced glycerine varies according to the vegetable oil used, the process used, and the amount of excess alcohol used. Both glycerine and biodiesel products have a substantial amount of the excess alcohol that is used in the reaction.

4. Removal of alcohol: The fatty ester produced in the upper layer is neutralized and vacuum distilled for removal of excess methanol.

5. Glycerine neutralization: The by-product glycerine contains unused catalyst and soaps in the upper layer that are neutralized with phosphoric acid resulting in potassium phosphate, if potassium hydroxide is used as a catalyst. The crude glycerine is sent for storage.

Methyl ester washing: The methyl ester produced from the reaction is then washed with hot water and separated out buy centrifugation. The transesterification process, involving transformation of the large, branched, triglyceride molecule into smaller, straight chain molecules.

TABLE I
PROPERTIES OF PALM BIO-DIESEL

Property	**Palm Bio Diesel**	**Diesel**
Kinematic viscosity at 40° C (cSt)	4.57	3.06
Density@15°c kg/m^3	879	833
Flash point (°C)	136°C	67°C
Fire point (°C)	153°C	138°C
Smoke point (mm)	15	14
Cetane number	62	52
Calorific Value (KJ/Kg)	40560	44800
Pour point (°C)	17°C	-25°C

III. EXPERIMENTAL SETUP

1. Single cylinder four stroke diesel engine
2. Eddy current dynamometer
3. Rotameter
4. Air box
5. Fuel tank
6. Burette
7. Fuel control valve
8. Load cell
9. Pressure sensor
10. Performance testing machine
11. AVL exhaust gas analyser
12. Exhaust probe

TABLE 2 ENGINE SPECIFICATION

Parameter	Specifications
Make	Brand new Kirloskar
Model	AV1
Method of cooling	Water cooled
Rated power	5 HP
Engine speed	1500 RPM
Bore × Stroke	87 mm × 110 mm
Volume	553 c.c
Compression Ratio	16.5:1

IV. EXPERIMENTAL APPROACH

Effect of HHO addition along with EGR before intake manifold is done at different loads to study the NOx emission and soot formation levels. Here we take three different fuel proportion to understand the nature of emissions. Initially readings are taken for diesel with EGR. Later on readings on B20 is carried out in a same manner. At last B20+HHO introduced and various performance and emission characteristics are recorded.

V. RESULTS AND DISCUSSION

5.1 Experimental Performance Data

Engine performance parameter like Brake power, brake specific fuel consumption and brake thermal efficiency respectively are discussed with diesel fuel, B20 and B20 with HHO at different load conditions.

5.1.1 Brake Power:

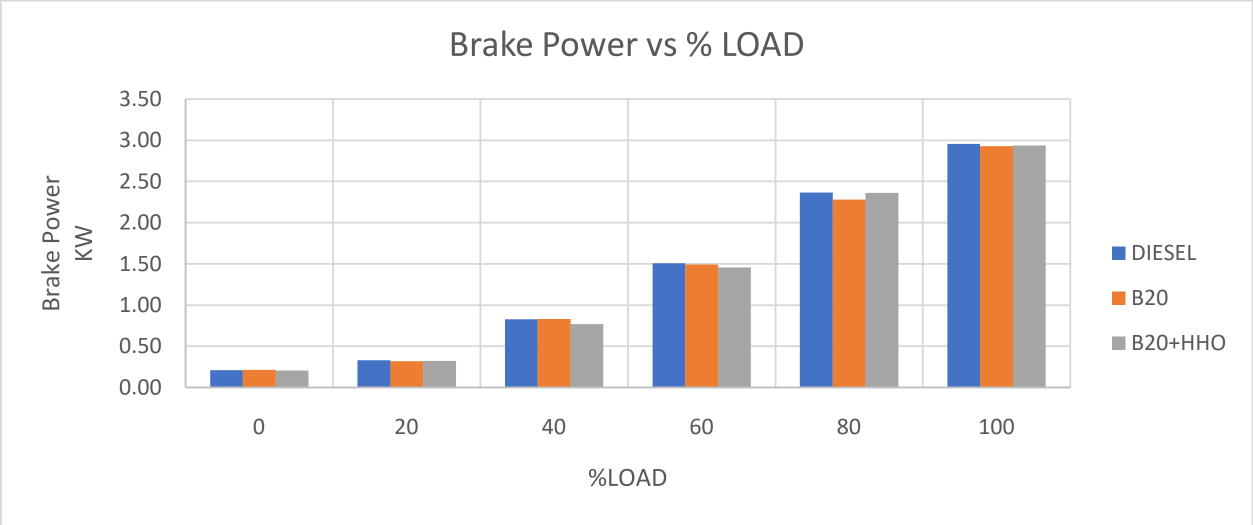

Figure 5.1 Brake Power vs % LOAD

Brake power with different load condition for all the tested fuels diesel, B20, B20 +HHO are mentioned in above graph. It has been observed that Brake power increase with increase in engine load for all tested fuels. Brake power for other fuels were slightly lower compared to diesel at all loads. Addition of HHO decrease Brake power at lower load and increase Brake power at higher load compared to B20. B20 decrease 2.56% average Brake power compared to Diesel. Addition of HHO increase average Brake power 3.08% respectively compared to B20.

5.1.2 Brake Specific Fuel Consumption:

Brake specific fuel consumption for all the tested fuels with various load conditions are shown as graph below. It has been observed that BSFC was decreased with increase in load for all the tested fuels. BSFC for B20 increased compared to Diesel at all the loads. Decrease in BSFC was observed for B20 after addition of HHO from load 0% to 60%. Average increase in BSFC for B20 compared to Diesel was 7.53%. Addition of HHO decreases average BSFC 6.15% compared to B20. Addition of HHO gives better BSFC compared to B20.

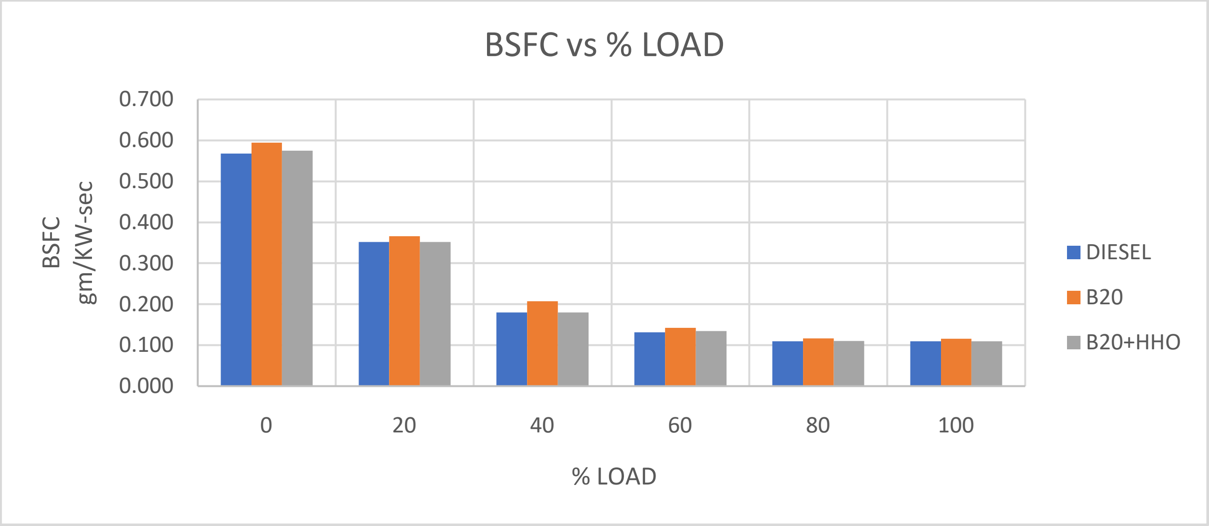

Figure 5.2 BSFC vs % LOAD

5.1.3 Brake Thermal Efficiency:

The brake thermal efficiency for all the tested fuels at different load condition are as shown in chart below. Brake thermal efficiency is lower than diesel for B20 at all the loads. For all the loads B20+HHO gives maximum BTE compared to all the tested fuels at all the loads. Average decrease in Brake thermal efficiency for B20 is 5.73% compared to Diesel. Addition of HHO in B20 increase 6.73% BTE, compared to B20.

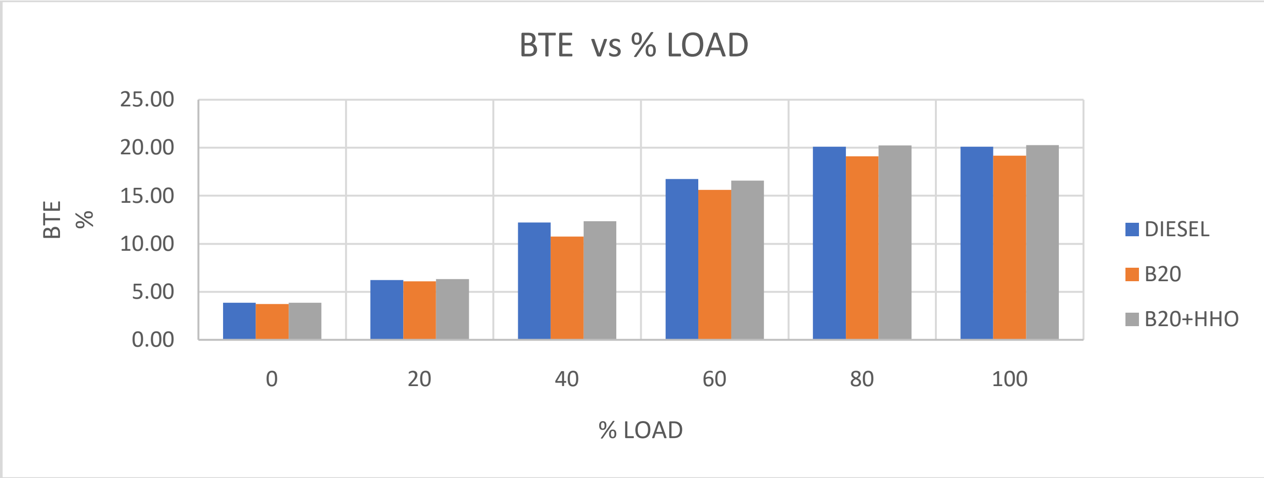

Figure 6.3 BTE vs % LOAD

5.2 Engine Emission Data

Variation of emission parameter like unburnt hydro carbon (HC), carbon monoxide (CO) and nitrogen oxide (NO) at different load conditions are recorded and discussed as below.

5.2.1 Hydro Carbon (HC):

As shown in above graph hydrocarbon emission for all the tested fuels is increasing as load increase. Compared to diesel B20 gives less HC emission at all the loads. Average decrease in HC emission for B20 compared to Diesel is 15.15%. Addition of HHO in B20 decreases the HC emissions at all loads.

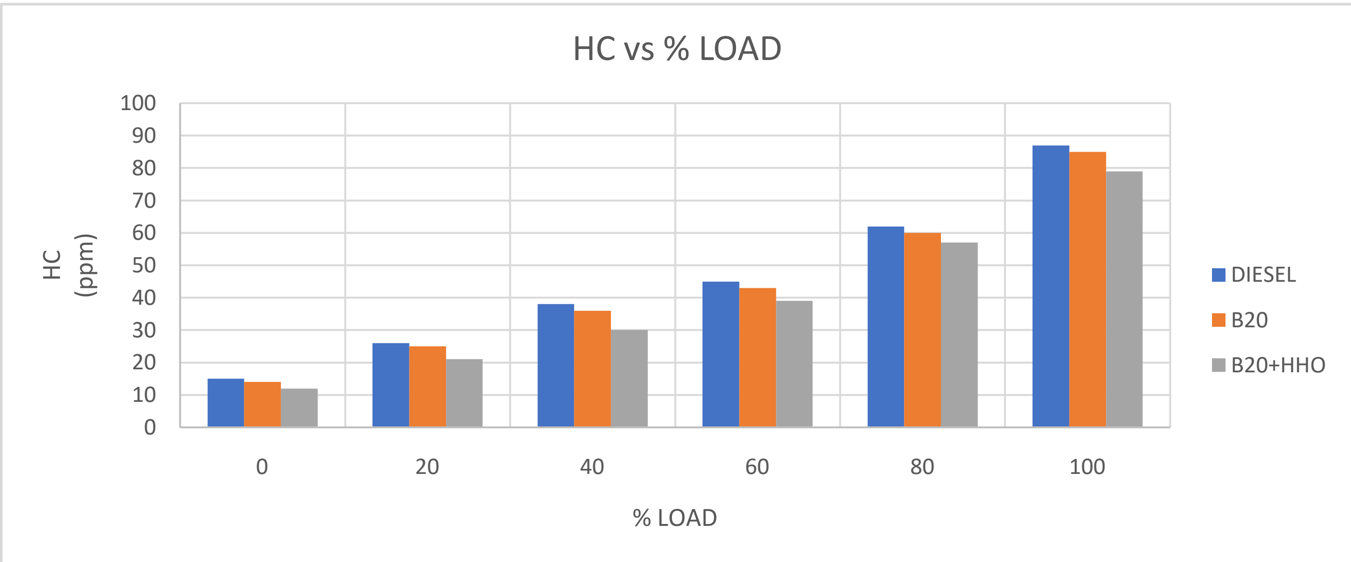

Figure 5.4 HC VS % LOAD

5.2.2 Carbon Monoxide (CO):

As shown in figure CO emission is lower for B20 compared to diesel at all the loads . Addition of BHA increase CO emission compared to B20 but it remains lower compared to diesel. Maximum CO emission is found with diesel because use of EGR system. Average decrease in CO emission for B20 compared to Diesel is 19.95%. Addition of HHO decrease CO emission by 15.91% compared to B20.

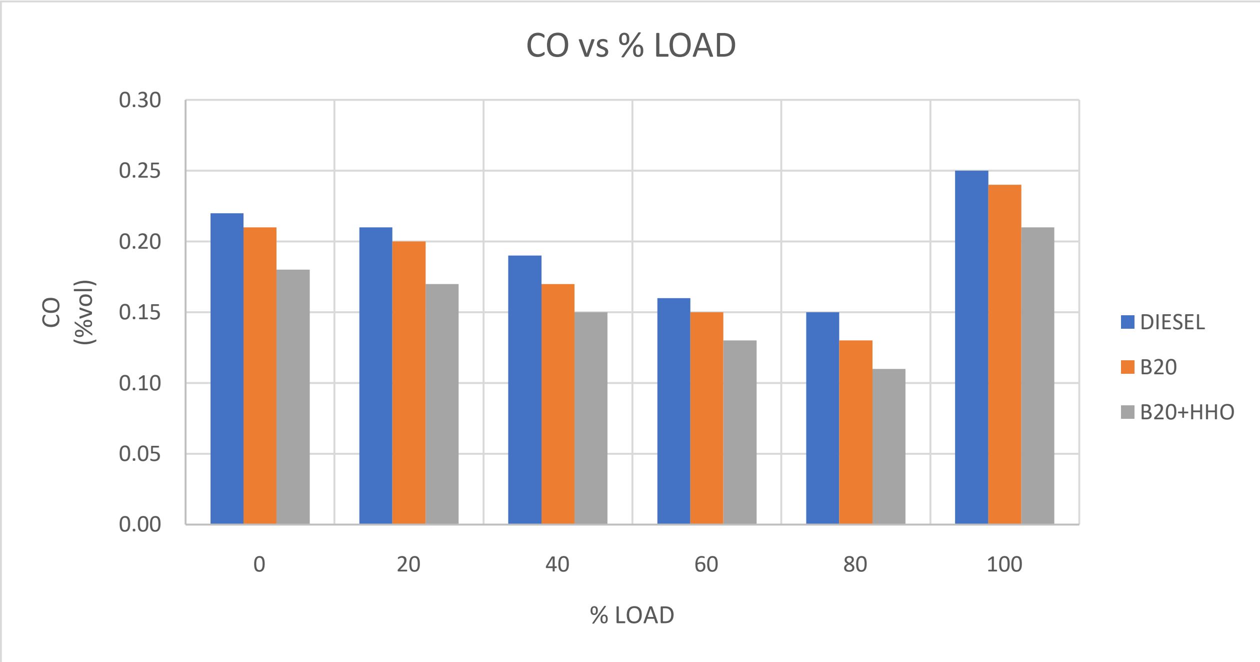

Figure 5.5 CO vs % LOAD

5.2.3 Nitrogen Oxide (NOx)

NOx emission for different loads is shown in figure above. B20 emits higher NOx compared to diesel at all the loads. To decrease higher emission of carbon soot when HHO introduced with EGR emission of NOx increased. Average increase in NOx emission for B20 compared to Diesel is 16.78%. Addition of HHO in B20 increases average NOx emission by11.82% compared to B20.

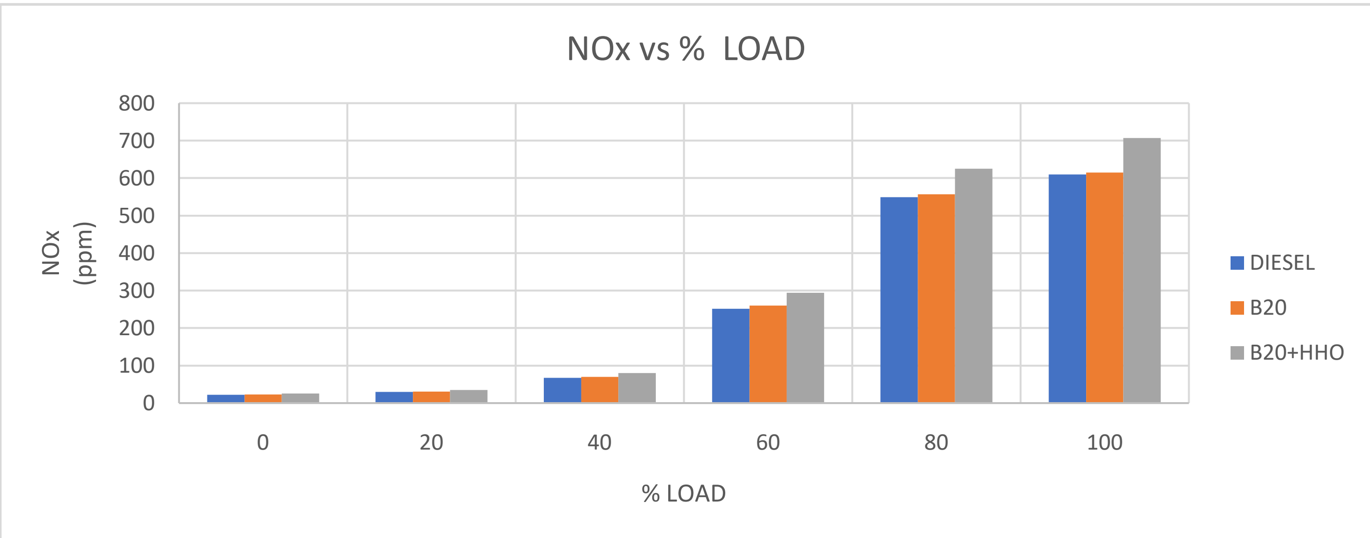

Figure 5.6 NOx vs % LOAD

VI. CONCLUSION

The aim of this experimental work was to investigate the effect of HHO on performance and emission characteristics of diesel engine fuelled with diesel-palm biodiesel blend. The following conclusions can be drawn based on the experimental results:

- Addition of HHO decrease Brake power at lower load and increase Brake power at higher load compared to B20. B20 decrease 2.56% average Brake power compared to Diesel. Addition of HHO increase average Brake power 3.08% respectively compared to B20.
- Decrease in BSFC was observed for B20 after addition of HHO from load 0% to 60%. Average increase in BSFC for B20 compared to Diesel was 7.53%. Addition of HHO decreases average BSFC 6.15% compared to B20. Addition of HHO gives better BSFC compared to B20.
- For all the loads B20+HHO gives maximum BTE compared to all the tested fuels at all the loads. Average decrease in Brake thermal efficiency for B20 is 5.73% compared to Diesel. Addition of HHO in B20 increase 6.73% BTE, compared to B20.
- Average decrease in HC emission for B20 compared to Diesel is 15.15%. Addition of HHO in B20 decreases the HC emissions at all loads.
- Average decrease in CO emission for B20 compared to Diesel is 19.95%. Addition of HHO decrease CO emission by 15.91% compared to B20.
- Average increase in NOx emission for B20 compared to Diesel is 16.78%. Addition of HHO in B20 increases average NOx emission by11.82% compared to B20.

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