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A Comparative Study between Hot EGR and CI Engine Using Mahua Oil Mixtures as Fuels

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Abstract

An investigation of CI engine using mahua oil methyl esters and its mixtures with hot EGR (HEGR) techniques has been investigated and presented. An optimum injection timing of 20 deg bTDC and injection pressure of 250 bar and is fixed and conducted the study. The emissions of mahua biodiesel and its mixtures with CI engine with hot EGR technique. The experimental test results are compared between Hot EGR and CI Engine (without adopting EGR technique). The same is compared and presented. For various test fuel samples, an increasing trend is noticed for various emissions for Hot EGR. The HEGR gave lower emissions at various loads. The neat biodiesel with Hot EGR (B100) gave greatest % reduction in NOx of 10.81% and 5.41% at minimum and maximum load. In general, EGR provides little bit higher NOx due to soot.

Keywords: *CI Engine, Emissions, Hot EGR, Madhuca Indica Bio-Diesel*

1.0 Introduction

In the globe, every country is focusing on renewable/ non- conventional energy sources such as vegetable oils to operate their Internal Combustion (IC) both SI and CI engines. Because non-renewable energy sources such as petroleum products (petro/diesel) comprises two important factors. The primary factor is the price of the petroleum products goes on increasing in every day and second factor is the petroleum fuels produce more exhaust emissions and in turn spoil our environment by producing toxic parameters such as smoke density, hydrocarbon, CO_x, SO_x and NO_x etc. Due to above issues, lots of researchers have been focusing on qualitative work on straight vegetable oil to operate IC engines. The present study concentrates on compression ignition (diesel) engine fuelled with straight vegetable oils. But unfortunately, straight vegetable (edible/non-edible) oil comprises more free fatty acids which give incomplete combustion due to greater viscosity and lesser calorific value.

To overcome the above issues, researchers have focused on esterification/transesterification process to produce bio-diesel for CI engine in unmodified form of engine spare parts. The non-edible and edible oils are the two important neat (or) raw vegetable oils. Non-edible oils are cheap and best with respect to availability and price as compared to edible oils. Keeping in mind, the present investigation involves 3 various non-edible oils have taken for their research work such as *Schleichera Oleosa* (Kusum), *Jatropha Curcas* (Jatropha) and *Madhuca Indica* (Mahua) oils. Using transesterification process, the bio-diesel has been produced by adding Methanol and Acid-Base catalysts in proper proportions. The normal CI engine releases more emissions especially, smoke density and NO_x. The present work focuses on Mahua biodiesel with hot and cold EGR with various fuel samples. The test results are compared and presented systematically.

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A qualitative literature survey was done on various fuel samples and presented.

The normal diesel study was done with jatropha and methanol fumigation process method and noticed that lower emissions but slight increase in CO and HC emissions[1]. A complete work has been done on normal engine with neat biodiesel and normal diesel and finally, the lower performance was obtained fuelled with base fuel while compared with mahua biodiesel[2,3]. A study was done on a twin-cylinder type engine. Better results were obtained with progressive injection time while compared with average and retard injection time[4]. The grasshopper optimization algorithm gave the optimum test results for CI engine performance parameters[5]. The soybean biodiesel gave higher SFC and reasonable emission reductions[6]. A CI engine was operated with EGR tool and provides lower NO_x emissions. Usages of EGR leads to engine wear due to little bit soot effects[7-9]. The *Thevetia peruviana* biodiesel was used on CI engine and found that lowest emissions except NO_x[10]. A trial was done with sunflower biodiesel with EGR. The B20 fuel sample gave lower emissions while compared with neat diesel. But little bit increase in BTE was observed[11]. A neat jatropha biodiesel and its fuel samples were used with EGR. It was noticed that increase in NO_x[12]. At various loads, The B25 mahua biodiesel with SCR technique gave better results especially drastic reduction in NO_x[13]. The lower injection timing and injection pressure give better results[14]. The B20 blend has been identified as optimum mahua biodiesel fuel and gave significant improvement[15].

From the literature review, it is seen that only limited work was done on diesel engine with pure biodiesel and EGR method. Not qualitative work has been done on Hot EGR (HEGR) fuelled with *Madhuca indica* fuel samples. The present work is focused on CI engine with HEGR at various fuel samples.

2.0 CI Engine Test setup

A schematic view of CI engine as shown in Figure 1 and technical work have been done on a 4S CI engine with eddy current dynamometer. The EGR technique/method such as Hot EGR has been adopted with CI engine at various loads for various test fuel samples.

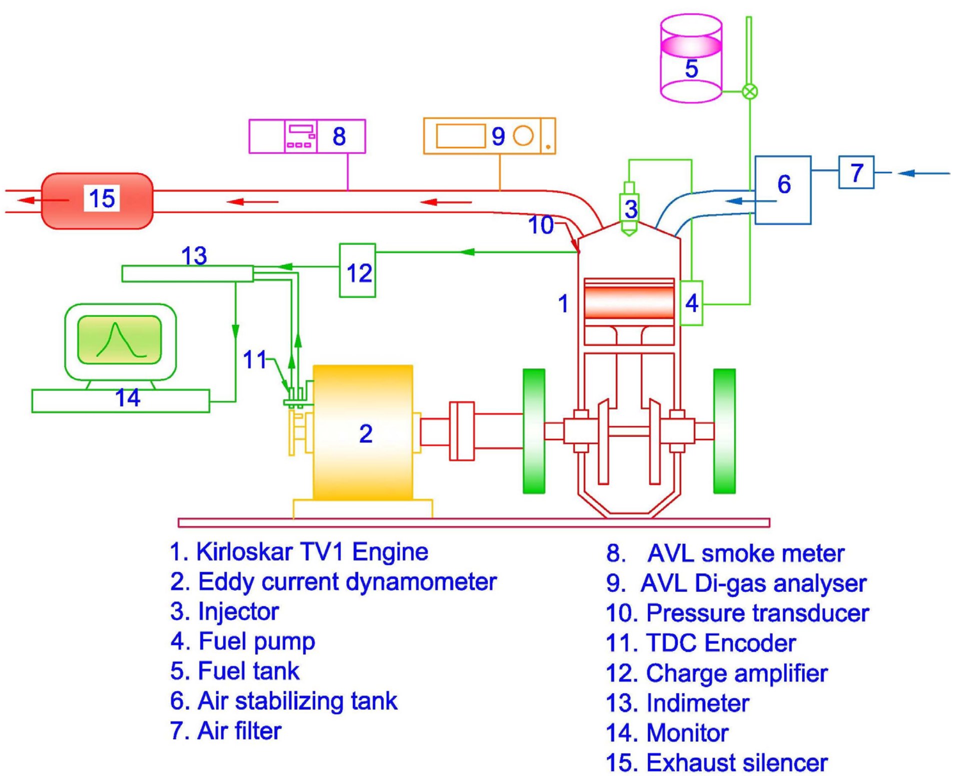

Figure 1. 2D Line Diagram of the engine components.

Table 1. Technical details of the engine with EGR

Type of the Engine with Make	Vertical Type, DI diesel Kirloskar TV - I Engine
Compression Ratio	17.5:1
Bore ✕ Stroke	(8.75 x11.0) cm
Rated Brake Power	5.2 kW
Constant Speed	1500 rpm
Injection Pressure and Timing	250 bar and 23 deg bTDC
Type of EGR	Hot EGR with 4 mm diameter and 30 mm manometer length

Injection pressure of 250 bar and timing of 23 deg bTDC are used to evaluate the performance of MOME in various mixtures with base fuel. The technical details are indicated in Table 1.

3.0 Mahua Biodiesel Thermo-Physical Properties

The properties of *Madhuca indica* fuel samples are measured and tabulated systematically (Table 2). An increasing trend is observed for viscosity (kinematic), flash and fire points while bio-diesel content rises. However, decreases trend has been observed for calorific value while biodiesel content diminutions.

4.0 Results and Discussions

4.1 SFC

The graphical representation (Figure 2) between SFC and BP for HEGR for various fuel samples. The HEGR gives lower SFC value at various loads. Among the various mixtures, the neat diesel and D-75 and B-25 fuel sample give minimum amount % increase in SFC. From Table 2, it could be noted that there is not much difference in CV of neat diesel and D-75 and B-25 fuel sample. The HEGR provides % reduction in SFC of 1.24% and 1.92% for D-75 and B-25 test sample fuel at minimum and maximum load while compared with CI engine (without adopting Hot EGR technique).

Table 2. Properties of various test fuel samples

Particular Details	D-100 & B-0	D-75 & B-25	D-50 & B- 50	D-25 & B-75	D-0 & B-100	ASTM Code
Gross calorific value in GJ/kg	0.0456	0.0439	0.0433	0.0425	0.0418	D4809
Specific gravity	0.82	0.83	0.85	0.87	0.88	D445
Acidity	0.06	0.07	0.07	0.08	0.26	D664
Cetane Number	46.00	51.60	51.70	51.80	52.40	D976
Flash Point in °C	65	71	78	112	170	D92
Fire Point in °C	70	79	88	123	183	D92
Viscosity (Kinematic) @ 40 deg C in cSt	2.60	3.50	4.10	4.90	6.00	D2217

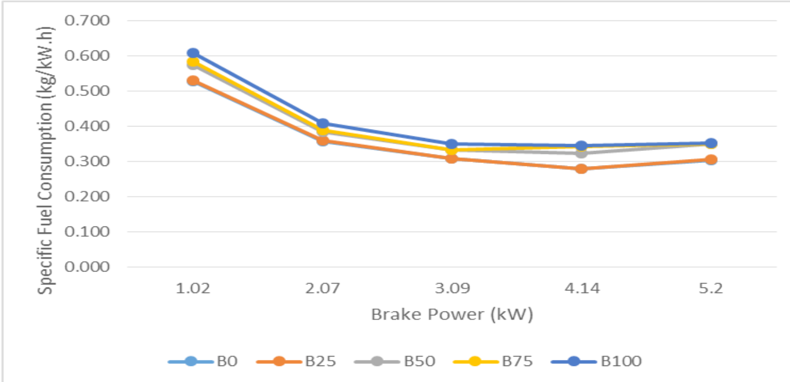

Figure 2. SFC versus BP.

4.2 BTE

The above Figure 3 indicates that the graphical representation between BTE and BP for HEGR for various fuel samples. It is found that there is a small difference (increase) in BTE in the case of HEGR while related with CI engine at various loads. Among the mixtures, pure diesel and D-75 and B-25 fuel sample give almost same and greater BTE value. The HEGR provides % increase in BTE of 2.08% and 2.41% for D-75 and B-25 sample fuel at minimum and maximum load while related with normal CI engine[11].

4.3 HRR

Figure 4 indicates that the graph between and crank angle and for HEGR for various fuel samples. Among the mixtures, neat diesel (D-100 and B-0) gives greater

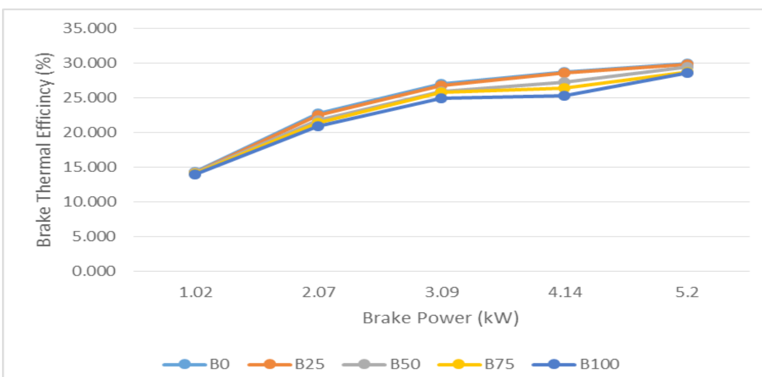

Figure 3. BTE versus BP.

Table 3. HRR (kJ/m^{3}deg) for various mixtures of HEGR

Crank Angle in deg	D-100 & B-0	D-75 & B-25	D-50 & B- 50	D-25 & B-75	D-0 & B-100
90	0.80	4.90	4.90	5.60	5.20
60	10.90	10.40	9.30	10.40	10.90
30	18.30	20.20	16.90	18.90	21.50
0	147.10	146.50	119.90	106.80	85.40
-30	-4.90	-4.00	-4.10	-4.20	-4.90

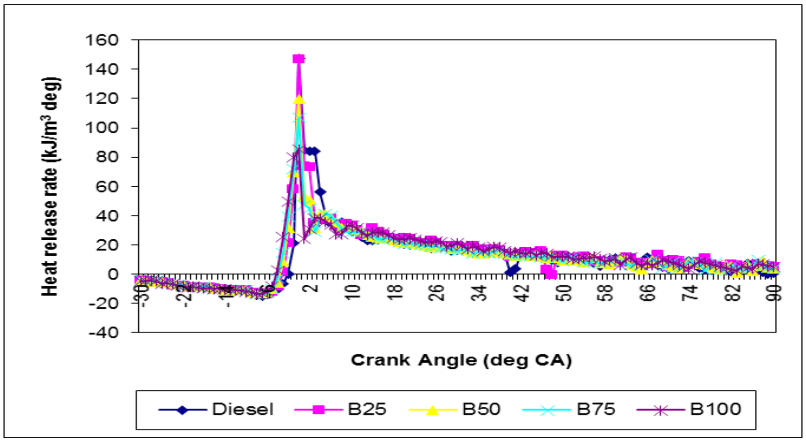

Figure 4. HRR versus crank angle.

HRR (kJ/m³deg) of 146.80 followed by D-75 and B-25 fuel sample (Table 3) the value of HRR (kJ/m³deg) is 146.5 whereas for neat biodiesel (D-0 and B-100) the value is 85.4 at 0 deg CA at maximum load. This indicates that better combustion take place for neat diesel. The % reduction in HRR for B100 is 42.03% at 0 deg CA. This is due to the reduction in CV by 8.28% for neat biodiesel while related with base fuel.

4.4 CO_2

Figure 5 indicates the graphical representation between CO_2 and BP for HEGR for various fuel samples. The HEGR gives little bit greater CO_2 while related with normal diesel engine at various load conditions. The D-75 and B-25 test fuel sample provides slightly greater CO_2 while compared to various test fuel samples. The % rise in CO_2 for a blend of D-75 and B-25 sample fuel is 2.78% and 1.17% at minimum and maximum while compared to neat diesel fuel. The % increase in CO_2 (with HEGR) for D-75 and B-25 test fuel sample is 5.41% and 2.71% while related with base fuel. The B25 test fuel sample gave better results[11]. The HEGR provides % increase in CO_2 of 5.45% and 2.31% for D-75 and B-25 test fuel sample at minimum load and maximum load while related with normal engine.

4.5 Smoke Density

Figure 6 indicates the graphical representation between SD and BP for HEGR for various fuel samples. The HEGR gives little bit lower SD emission. As compared to all

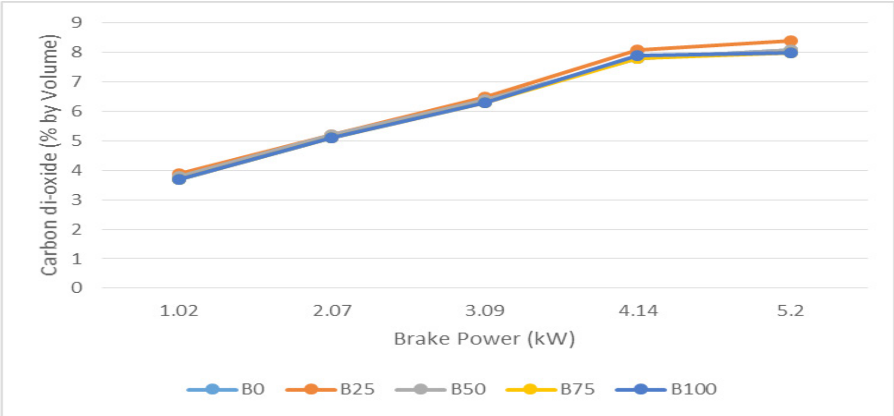

Figure 5. CO_2 versus BP.

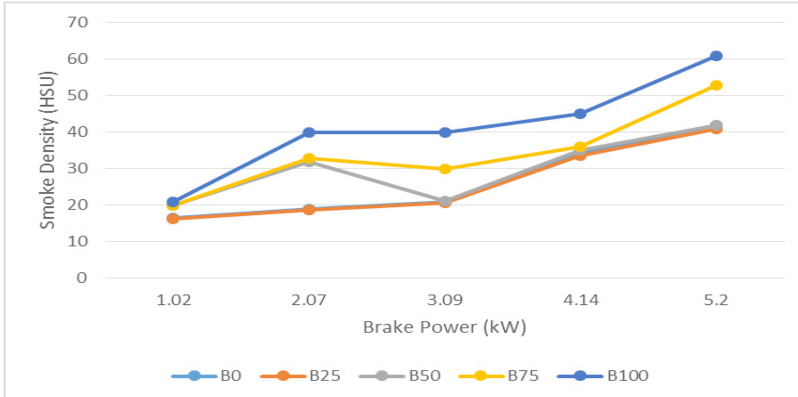

Figure 6. Smoke density versus BP.

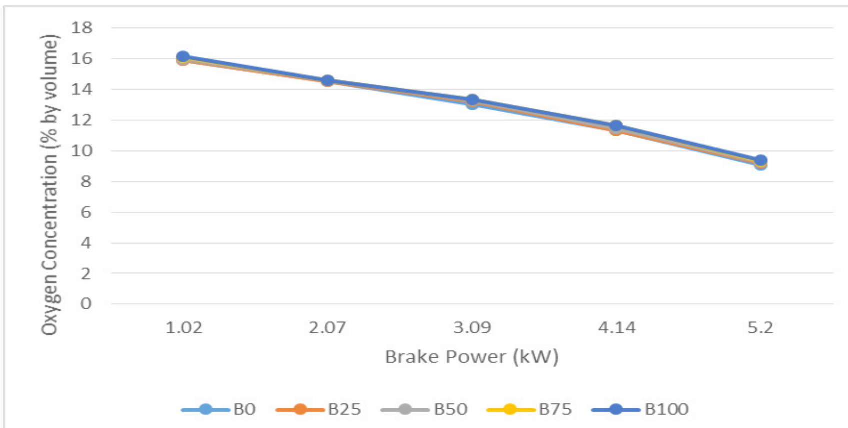

Figure 7. Oxygen Concentration versus BP.

other test fuel samples, the D-75 and B-25 emits lowest SD at various loads. The HEGR, the D-75 and B-25 test fuel sample also gave lowest SD of 1.71% and 2.38% while compared with neat base fuel at no and full loads.

4.6 Oxygen Concentration

The above Figure 7 indicates the graphical representation between O_2C and BP for HEGR for various fuel samples. The HEGR provides lowest O_2 concentration while related with CI engine. The HEGR, neat diesel provides lowest O_2 concentration of 15.9% and 9.1% whereas the D-75 and B-25 test fuel sample gave the almost same O_2 concentration as that of base fuel. But neat biodiesel provides little bit higher O_2 concentration of 16.2% and 9.4% while compared with all test fuel samples. As compared with D-100 and B-0, the % rise in O_2 for neat biodiesel is 1.60% and 3.30% respectively at minimum and maximum load with HEGR.

4.7 Hydrocarbon

Figure 8 indicates the graphical representation between HC and BP for HEGR for various fuel samples. The neat biodiesel emits lowest HC of 0.012 and 0.032 at minimum and maximum load while related with other fuel samples. At minimum and maximum load, the % lessening in HC for neat biodiesel (percentage), is 33.33 and 5.88 respectively while related with neat diesel. At minimum and maximum load, the % reduction in HC for neat biodiesel, is 38.89% and 6.06% respectively while related with neat diesel. The HEGR gives greater % reduction in HC of 8.33% and 3.13% for neat biodiesel at minimum and maximum load while compared with CI engine.

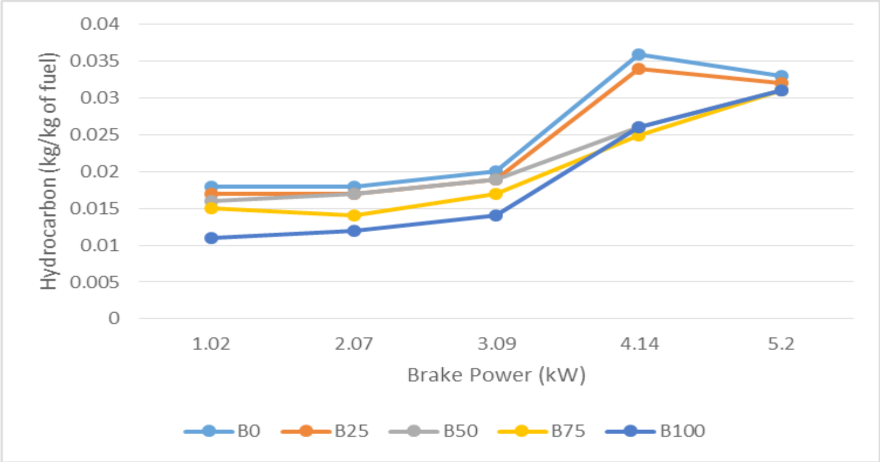

Figure 8. Hydrocarbon versus BP.

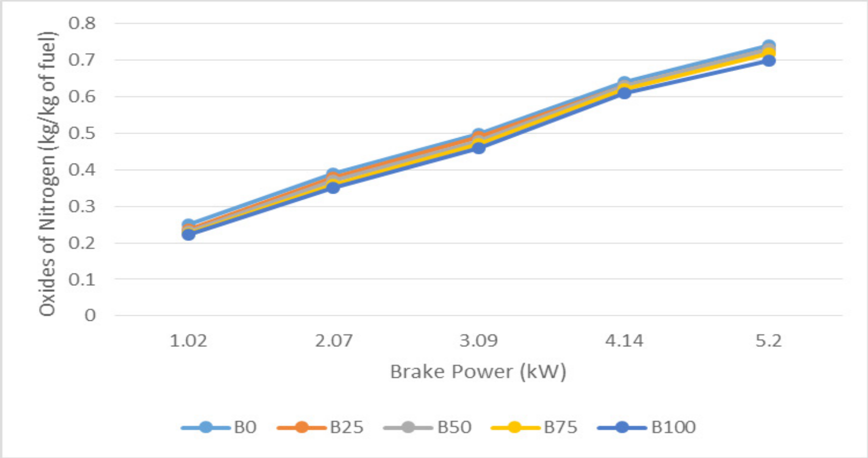

Figure 9. NO_x versus BP.

4.8 NO_x

Figure 9 show the graphical representation between NO_x and BP for HEGR for various fuel samples. The HEGR provides highest % reduction in NO_x of 7.08% and 5.41% while compared with CI engine at minimum and maximum load respectively.

5.0 Conclusions

Because biofuel has a greater flash point than base fuel and since its lesser exhausts of PM, CO, NO_x, SO_x and possibly other air poisonous, it could lesser exhausts levels in mines, diminish the price of giving bearable ventilation circulation in mines, and enhance the performance level. From the results, it is noted that the HEGR provides lesser exhausts such as O_2 concentration, HC, SD and NO_x while compared with CI engine. The neat bio-diesel emits lower emissions at various loads. At last, it is concluded that the neat biodiesel with HEGR give lowest emissions at various loads while compared with CI engine. The HEGR provides almost and comparatively control the NO_x. But EGR leads soot formations.

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