Performance Characteristics & Emission Analysis Of Mustard Oil Based Biodiesel In CI Engine Using Exhaust Gas Recirculation

Elavarasan.G, Kannan.M, Thiagarajan.L, Karthikeyan.D

Abstract— Increase in the price of crude oil and the release of harmful emissions from the automobiles force researchers to search for an alternative source of energy for fueling. Biodiesel production from plant seed have become a promising alternative fuels for diesel powered engines. The biodiesel was extracted from the mustard oil and it was blended with the diesel in the ratio of MB10 (10% Mustard Biodiesel, 90% diesel), MB20 (20% Mustard Biodiesel, 80% Diesel), and MB30 (30% Mustard oil, 70% Diesel), MB40 (40% Mustard Biodiesel, 60% Diesel), MB50 (50% Mustard Biodiesel, 50% Diesel). The blends were tested in a single cylinder, constant speed (1500 rpm) diesel engine with 15% of exhaust gas recirculation (EGR). The performance and emission characteristics were measured for various diesel blends. The results shows that the Brake thermal efficiency (BTE) was decreased about 3% to 4% as the specific fuel consumption is increased for all the blends. The smoke and CO emissions were found to be decreasing with increase in the blend, the maximum decrease of 35% and 53% was observed for MB50 blend of smoke and CO emissions respectively. The NOX emission was reduced about 40% because of the increase in the combustion temperature and pressure for M50 blend.

Index Terms— Alternate fuel, Biodiesel, Emission characters, NOX reduction by EGR, Mustard oil, Performance characters, Emission control.

1 INTRODUCTION

The crude oil reserves of our country is only about 0.3% of the world reserves, it creates a necessity to shift towards an alternative source of fuel that can be used in existing running vehicles without any modification of the engine [1]. The compression Ignition (CI) engines are more suitable for using the alternate fuel directly into the engine, as it requires very less engine modification [2]. The most identified alternative source of fuels is biodiesel extracted from the vegetable oils [3]. So, this area has becoming more and more attractive among the researchers to investigate its performance characteristics as a fuel in the CI engine [4]. The vegetable oils are mostly triglycerides with presence of more amount of mono saturated fatty acid, so it is used for the biodiesel production. [5] & [6]. Vegetable oil contains glycerol in it and it should be removed before using it in the engine which can be done in the trans-esterification method [7]. Many researchers suggests that the use of vegetable oil biodiesel blended with diesel will reduce emissions like HC and CO mare than that of the engine powered by diesel alone [8 -9]. The oil seeds used for the production of biodiesel can be selected according to its availability in the environment [10].We have taken mustard oil as a source for the production of the biodiesel, as it yields 227 to 531 liters per acre [5]. The free fatty acid present in the mustard oil was removed by trans-esterification process [11]. Mustard oil biodiesel was blended with diesel in various ratios, 10% mustard biodiesel and 90% diesel (MB10), 20% mustard biodiesel and 80% diesel (MB20), 30% of mustard biodiesel and 70% of diesel (MB30) and 100% diesel (Diesel). The blends were tested in a single cylinder diesel engine at a constant speed of 1500 rpm for various brake powers (1.1 kW, 2.1 kW, 3.1 kW, 4.2 kW, 5.2 kW) [12] to find its combustion, performance and emission characteristics. The less volatility and high viscosity of the MB fuel lead to the formation of more HC and CO emission but oxygen content in the mustard oil enhanced the oxidation of HC and CO and thereby reduced the CO and HC emission was observed with increase in blend. However, the formation of the NOX emission is more and this can be reduced by adding 15% EGR. The EGR concentration in the inlet can be controlled and varied according to NOx concentration in the exhaust gases which depends on various operating conditions. But a constant of 15% of EGR was taken in our study [13]. The obtained results indicate that the brake thermal efficiency was decreased with increase in the biodiesel blend percentage [14]. The HC and CO emissions were reduced with increase in the blend percentage; this will play a vital role for the upcoming stringent emission norms of our country [15]. For the blend MB50 with 15% EGR, the maximum CO and HC recorded were 22% and 18% lesser than that of the diesel fuel respectively. However the NOX emissions of MB50 with 15% EGR were decreased about 55% less than diesel fuel with 15% EGR.

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2 Preparation of Biodiesel

The pure mustard oil was obtained commercially and converted into biodiesel by trans-esterification process. Methanol was mixed with sodium hydroxide and well stirred for some time. The treated methanol was poured into the mustard oil and it was stirred continuously, heated and maintained at a temperature around 65°C for an hour, then the solution was transferred to the conical separation funnel [16]. After 5-7 hours, the fatty acid in the form of glycerol was settled at the bottom of the funnel and the biodiesel was present at the top [17]. The glycerol was removed and the biodiesel was washed with deionized water to remove the extra soap content or glycerol and the final product is heated again to remove any traces of water particles and finally, taken for testing [18].

2.1 Properties of Biodiesel

The mustard oil biodiesel was tested according to ASTM standards to find out its properties and was compared with diesel properties. The properties of diesel and mustard oil were given in table.1.

Table.1.Properties of Mustard oil Biodiesel [19] and Diesel

S.No	Properties	MB	Diesel
1	Kinematic Viscosity	6.6 mm2/s	4.2 mm2/s
2	Flash point	105˚C	57
3	Fire point	125˚C	74
4	Cloud point	-6 ˚C	-12 ˚C
5	Pour point	-12 ˚C	-23 ˚C
6	Density	0.895 g/ml	0.841 g/ml
7	Cetane Number	50	55
8	Calorific value	39857 kJ/kg	45343 kJ/kg

3 Experimental Method

The biodiesel is mixed with the diesel fuel in the ratio of 10:90, 20:80 & 30:70, 40:60 & 50:50 by volume and was tested in a single cylinder with EGR at a speed set constant at1500 rpm and the corresponding experimental layout was shown in the figure.1.

Table.2 IC Engine set up specification

Make	Kirlosar-TV 1
General details	Four stroke, compression ignition, water cooled, direct injection
Bore	87.5 mm
Stroke	110 mm
Compression ratio	17.5:1
Rated speed	1500 rpm
Injection pressure 220 bar	220 bar
Fuel injection timing	23 BTDC
Rated output	5.2 kW
Speed	1500 rpm

The specification of the engine used for the testing is shown in the table.2. Initially engine was allowed to run with Diesel fuel with 15% EGR and then engine was run with MB10, MBD20 & MBD30, MB40 and MB50 with 15% EGR at different brake powers by varying the load on the engine using eddy current dynamometer to find engine combustion, performance and emission characters.

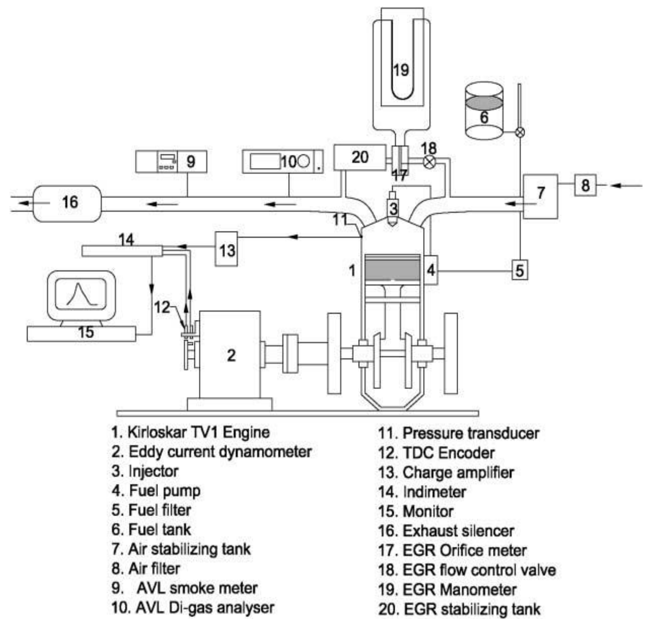

Figure.1. Experimental Layout

Then the performance and characters and the amount of smoke emission released for the various operating conditions were recorded with the help of a AVL 413 Smoke meter. The harmful emissions like HC, CO & NOX were measured with the help of AVL DIGAS 444 Analyzer. The EGR will affect the emission by decreasing the level of NOX and increasing the smoke emission

4 RESULTS AND DISCUSSIONS

4.1 Brake power Vs Brake Thermal Efficiency

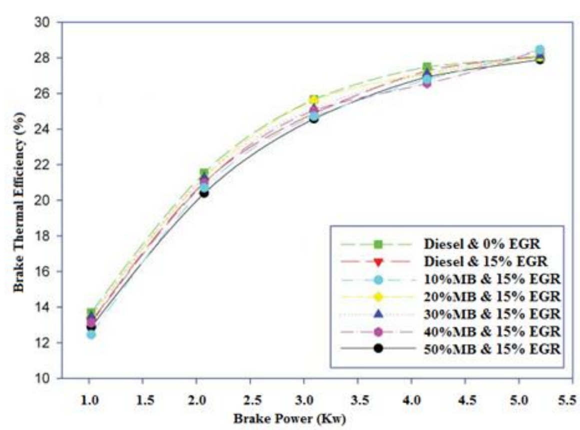

Figure.2. BP in kW vs BTE in %

The figure.1 indicates that the BTE was maximum for diesel fuel compared to that of the mustard oil biodiesel blends, As the mustard oil have lesser calorific value and more specific fuel consumption than diesel the brake thermal efficiency is decreasing with increase in blend of the biodiesel[19].

4.2 Brake power Vs Specific fuel Consumption

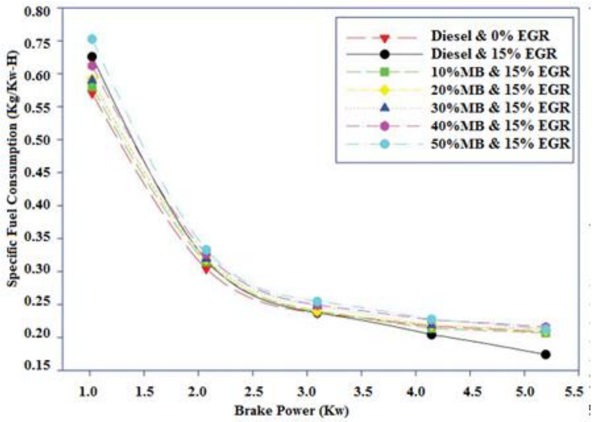

Figure.3. BP in kW vs Specific fuel consumption in kg/kWh

SFC is the amount of fuel used to produce a unit brake power. The Figure.3 indicates that the specific fuel consumption of the fuel is increased with increase in the biodiesel blend. The MB50 is having the maximum specific fuel consumption as the oxygen content of the fuel will increase with increase in the biodiesel blend in diesel [20]. The viscosity of the diesel is very less, the restriction for the fuel flow is more and the vaporization and the atomization of the fuel is less than that of the diesel so the MB50 is having the higher SFC [21].

4.3 Brake Power vs smoke emission

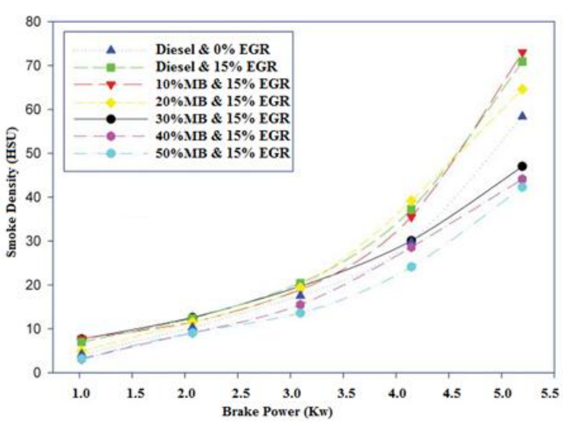

Figure.4 BP in kW vs smoke (HSU)

The figure.4 shows that the smoke emission is reduced with increase in blend. MB50 with 15% EGR has the minimum smoke emission. It is because of the lesser sulfur content in the MB50 fuel [22]. The increase in load will increase the smoke emission for all the blends. Normally the addition of EGR will increase the smoke emission, But the presence of more oxygen content in the Biodiesel will prevent the formation of smoke emission.

4.4 Brake power Vs CO Emission

Figure.5 shows that the CO emission for the MB50 was low as there is more oxygen available the CO is oxidized to CO2. Thus the MB50 have the lesser CO emission compared to other type of blends [23].

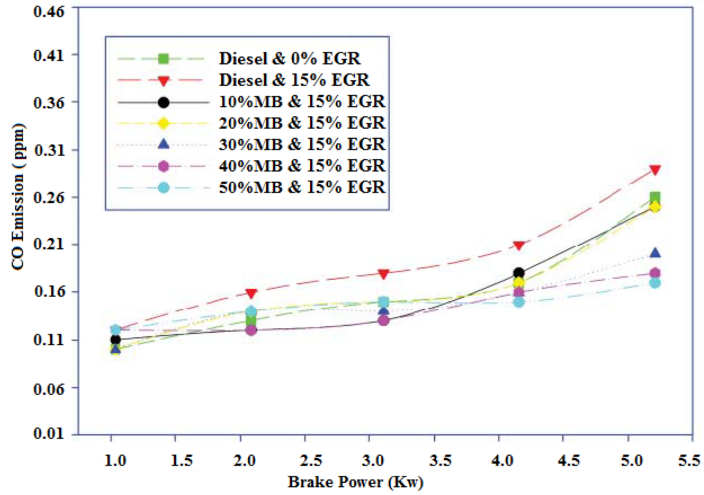

Figure.5 BP in KW vs CO emission in ppm

4.5 Brake power Vs NO_X Emission

From the figure.5 it is clear that the formation of NOX emission is more in MBD15 compared to MBD0. As the oxygen content is high in the mustard oil biodiesel the combustion process will be perfect. If the combustion process is perfect then the formation of the Nitrogen Oxides emissions will be more [24], So the NOX emission is more with increase in the blend percentage.

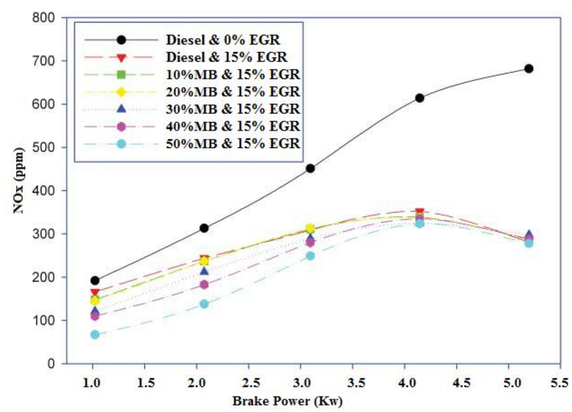

Figure.6 BP in KW vs NOX emission in ppm

4.6 Brake power Vs HC Emission

The Figure.6 shows the HC emission of all blends, The MB50 shows the minimum HC emission and the Diesel with 15% EGR have the maximum HC emission [25]. The EGR will restrict the complete combustion, but the MB fuel burns all of its droplets inside the combustion chamber, there is no unburned HC in the combustion chamber. The cetane number will increase with the addition of biodiesel blend and the biodiesel blend of MBD50 will have less HC emission.

4.7 Crank Angle Vs Cylinder Pressure

Figure.7 shows the maximum cylinder pressure developed inside the cylinder for different MB blends. The maximum pressure obtained is 73.305 bar for the MB50 with 15%EGR. The fuel atomization is the prime factor for the pressure development inside the cylinder. It is also observed from the figure that the peak pressure developed for the mustard oil is between 5 and 15 degree of crank angle.

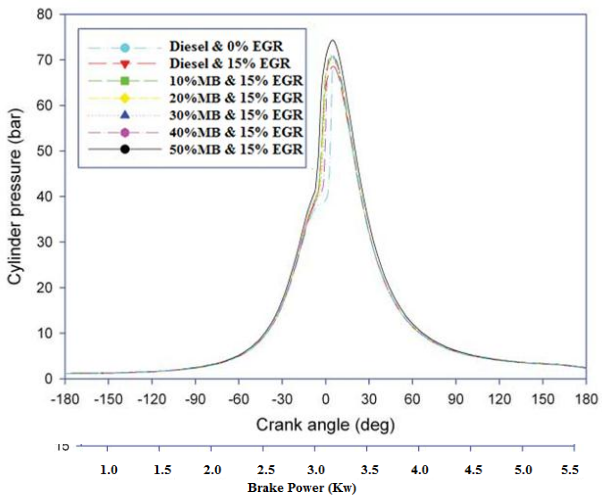

Figure.7. Crank Angle in degree Vs Cylinder Pressure in bar

4.8 Crank Angle Vs Heat Release Rate

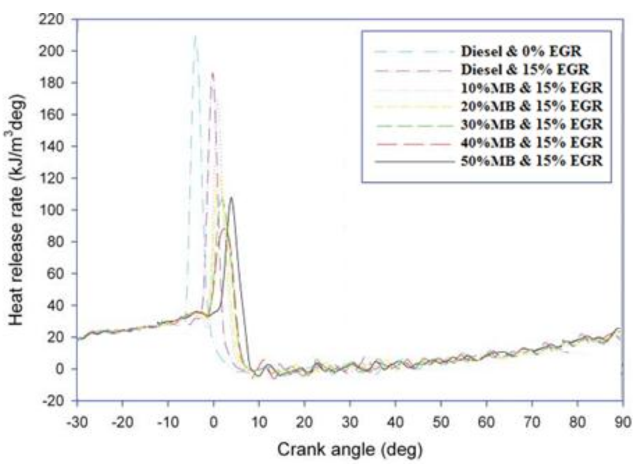

Figure.8. Crank Angle Vs Heat release rate

Figure.8 shows the Heat release rate of Diesel and various MB blends, As the calorific value of diesel is more than that of the mustard oil the heat release rate of diesel without EGR is maximum. And the heat release rate is decreasing with increase in the MB blend in diesel.

5 CONCLUSION

Thus the mustard biodiesel was produced and blended with the diesel in various ratios, it was then tested in a single cylinder diesel engine. Its performance and efficiency characters were found.

- Specific fuel consumption was increased with increase in MB blends, but it is near to that of diesel, only around 3% variation.
- Brake thermal efficiency was decreased to an acceptable level with increase in MB blends.
- HC and CO emissions were reduced with increase in MB blends, For MB50 with 15% EGR, a maximum of 18% and 22% reduction than that of diesel fuel was observed.
- As there is complete combustion in the engine with MB fuel, NOX emission was increased with increase in MB blends. It was reduced about 50% lesser than that of diesel with the help of 15% EGR

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