A Study on Reduction of Oxides of Nitrogen with Jatropha Oil Based Bio Diesel

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Abstract- The Continuous depleting oil resources and stringent emission norms leads to increase in interest in Biodiesel fuel. Biodiesel is a renewable fuel made from vegetable oil or animal fats. World's maximum biodiesel is produced from edible oils, raising the concern for the global scarcity of edible oil supply. In order to defeat the situation, research has been conducted to produce biodiesel by using non-edible oils like Jatropha. Jatropha Biodiesel (JOME) is being accepted as promising renewable alternatives to diesel fuels. Jatropha Biodiesel have advantages over the conventional diesels, as they are known to produce reduced emissions like CO, HC and Smoke, but the NOx Emission is found to be increased. Use of the Cooled Exhaust Gas Recirculation (EGR) system is one of the most effective techniques currently available for reducing NOx. In the present study performance and emission parameters of a four stroke four cylinder diesel engine fuelled with neat Jatropha Biodiesel with cooled EGR is experimentally investigated. The study showed that the effect of increased NOx emission was found to be reduced with the EGR.

Keywords- Diesel Engine, Biodiesel, Performance, Emission, NOx Reduction, Exhaust gas Recirculation.

1. Introduction

The internal combustion engine is one of the key drivers in modern industrial society. Without the transportation performed by the millions of vehicles, we would not have reached the living standard of today [1]. The use of alternative fuels in engines has been the focus of much attention because of increasing concerns about environmental protection and the shortage of crude oil [2]. Vegetable oils have been extensively studied by many researchers as an alternative fuel of Diesel Engine [3-7]. Vegetable oils have their own advantages: first of all, they are available everywhere in the world. Secondly, they are renewable as the vegetables which produce oil seeds can be planted year after year. Thirdly, they are ''greener'' to the environment, as they seldom contain sulphur element in them. This makes vegetable fuel studies become current among the various popular investigations [8]. The use of raw vegetable oils in engines without any modification results in reduced performance and leads to wear of engine components [9]. The problems faced with raw vegetable oils as fuels are poor atomization due to their high viscosity, severe engine deposits, injector coking, and piston ring sticking and incomplete combustion leading to higher smoke density [10-11].

Transesterification is the process of reducing the oil viscosity by conversion of triglycerides into the esters of the particular vegetable oil. These esters are called biodiesel. It is non toxic and biodegradable. Its higher flash point and low volatility, makes biodiesel safer fuel to handle. Its combustion behaviour shows potential substitute as a diesel fuel. Many researchers have reported almost similar performance of engines fuelled with Biodiesel of different feed stocks [12-16]. Exhaust emission like carbon monoxide (CO), Unburned Hydrocarbon (HC), Smoke was found to be reduced, but the Nitrogen oxides (NOx) emission was increased when compared with the diesel fuel [17-20]. NOx emission needs to be reduced to make Biodiesel more viable.

The exhaust gas recirculation (EGR) is one of the effective methods for reducing the NOx [21-23]. EGR involves the re circulating the part of exhaust gases back to the intake manifold. There are two types of EGR system, internal EGR and External EGR. Internal EGR system uses the variable valve timings or other devices to retain a certain fraction of exhaust gases from the previous cycle. External EGR system uses the external pipeline to route the gases back to the intake manifold, directly or after cooling, to mix with the fresh air [24]. Exhaust gases contains mixture of Carbon monoxide, nitrogen, water vapours etc. Exhaust gases displaces the fresh oxygen for the combustion. The mixture has higher specific heat compared to the supplied fresh air, this increases the total heat capacity of the working gases in the engine cylinder and thus lowers the peak gas temperature and reduces rate of NOx formation [25-32].

In the present work, Biodiesel was prepared from the Jatropha oil and an attempt has been made to experimentally investigate the performance and emission parameters of Exhaust gas recirculation on a Jatropha Biodiesel fuelled Diesel engine.

2. Experimental Methodology

2.1. Production of Jatropha Oil Methyl Ester

A biodiesel reactor of 10 Litres capacity was used for the present study. Jatropha oil was heated initially to about 60^{o}C in the reactor. 40% Methanol (99.9% pure) and 0.75% potassium hydroxide was mixed separately to dissolve and added to the heated Jatropha oil. The mixture was stirred for around 1.3 hours at a fixed temperature of about 60^{o}C, it was allowed to cool and separate the layers of glycerol and methyl ester. The impurities and the glycerol settled at the bottom part of the reactor where as methyl ester formed at the upper part of the reactor. A valve at the bottom part of the reactor was used to remove initially the heavy glycerol than the methyl ester. The yield of Jatropha oil methyl ester was approximately 85%. After that, a washing process using heated distilled water was carried out to remove some un-reacted remainder of methanol and catalyst which if not removed can react and damage storing and fuel carrying parts. During washing ester present react with water and can form soap thus gentle washing was used. After washing two distinct layer formed with bottom layer having water and impurities settled down and removed. A heating process at about 60^{0}C was applied for removing water contained in the esterified Jatropha oil and finally, left to cool down.

2.2. Fuel Properties

The fuel properties were determined and are listed in Table 1, for Jatropha Biodiesel and diesel.

Table 1. Fuel properties of Diesel and Jatropha Biodiesel

Properties	**Test Method**	**Diesel**	**Jatropha Biodiesel**
Kinematic viscosity @40^{0}C, cSt	D445	2.4	5.8
Density @ 15^{0}C	D1298	822.4	893.2
Flash Point ^{0}C	D93	67	167
Net Calorific Value, MJ/kg	D240	42.7	38.92
Water and sediments %volume	D2709	0.01	0.02
Sulfur, %wt	D4294	0.28	Nil

2.3. Experimental Setup

The experimental setup shown in Figure 1 consists of a four cylinders, four stroke, naturally aspirated diesel engine, an engine test bed with hydraulic dynamometer. The specifications of the test engine are given in Table 2. The test bed contains instruments for measuring various parameters such as engine load, air flow by anemometer, gas temperatures by K type thermocouples. The fuel consumption was determined by weighing the fuel on an electronic scale. For the analysis of the exhaust gases, Eurotron green line gas analyzer and AVL 437 smoke meter was used.

The External EGR system was created by using External pipeline to route the part of exhaust gases coming out from the engine to the suction manifold. An external valve is used to control the flow rate. The exhaust gases were cooled with an EGR cooler by using water. The EGR rate was determined by

$$\text{EGR rate} = 100 \text{ X } (Q_{\text{without EGR}} - Q_{\text{EGR}}) / Q_{\text{without EGR}} \ \%$$

Where Q without EGR is air flow rate before EGR where as QEGR is the air flow rate using EGR.

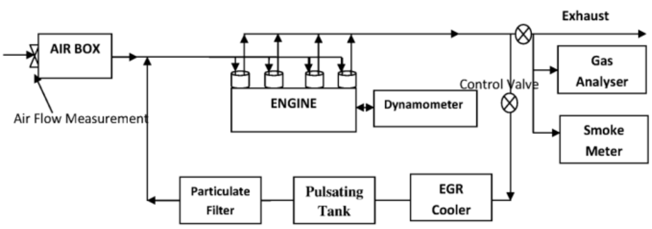

Fig. 1. Experimental Setup

Table 2. Test Engine Specification

Make	Force Motors
Cylinder Number and type	Four, Four stroke
Rated Power (H.P.)	27
Rated speed	2200 rpm.
Bore(mm)	78
Stroke(mm)	95
Compression Ratio	18.65:1

2.4. Experimental Test Procedure

The engine was allowed to reach its steady state by running it for about 10 minutes. The engine was sufficiently warmed up and stabilized before taking all readings. After the engine reached the stabilized working condition, the load applied, fuel consumption, brake power and exhaust temperature were measured, the values were recorded thrice and a mean of these was taken for comparison. The engine performance and Exhaust emissions were studied at different loads. The brake specific fuel consumption, brake specific energy consumption and thermal efficiency were calculated. The emissions such as CO, HC, and NOx were measured using exhaust gas analyzer and smoke with smoke meter. These performance and emission characteristics for different fuels are compared with the result of baseline diesel.

3. Results and discussion

The test fuels used during this study were neat Jatropha Biodiesel and a neat diesel. Experiments were conducted at a constant speed of 2000 rpm and by varying the loads. The rate of EGR was limited to 10 percent as the high rate can deteriorate the combustion characteristics. The different performance and emission parameters are discuss below.

3.1. Brake Specific Energy Consumption

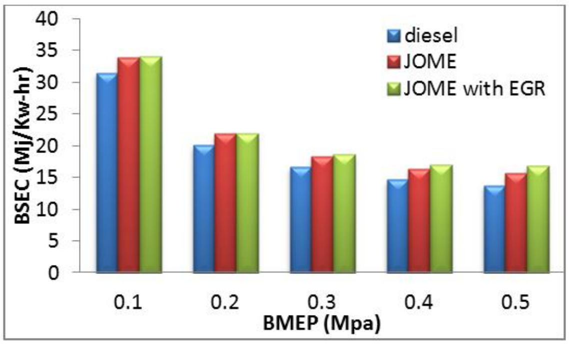

Fig. 2. BSEC of Jatropha Biodiesel versus BMEP

Variation of Brake specific energy consumption (BSEC) with respect to Brake mean effective pressure is presented in Figure 2. BSEC is better criterion than Brake specific fuel consumption (BSFC) to compare two fuels of different calorific value. BSEC was found to be decreased with increase in loads. Jatropha Biodiesel showed an average of 10.4 percent higher energy consumption than the diesel fuel. The increase in energy consumption of Jatropha Biodiesel may be attributed to the viscosity of Biodiesel which makes the atomization of the Biodiesel little difficult. Jatropha Biodiesel when used with the EGR showed an average increase of 2.61 percent in energy consumption compared to without EGR and 13.3 percent compared to neat diesel fuel. This may be due to the penalty of exhaust gases containing CO2 made the combustion difficult.

3.2. Brake Thermal Efficiency

Brake Thermal Efficiency (BTE) indicates the capability of the combustion system to accept the experimental fuel, and provides comparable means of assessing how efficient the energy in the fuel was transformed to mechanical output [34]. Figure 3 presented the trend of Brake Thermal efficiency with the BMEP. It was observed that it increase with increase in load. The maximum thermal efficiency was observed for the Diesel fuel. Jatropha Biodiesel showed an average reduction of 9.36 percent in BTE. The use of EGR showed increased fuel consumption and hence lower brake thermal efficiency. EGR on Jatropha Biodiesel results on an average 2.48 percent reduction in BTE compared to without EGR and 11.6 percent compared to neat diesel fuel. Effect of EGR was found to be more pronounced at higher loads. The possible reason could be deficiency in oxygen concentration in combustion process and larger replacement of air by the exhaust gases [35].

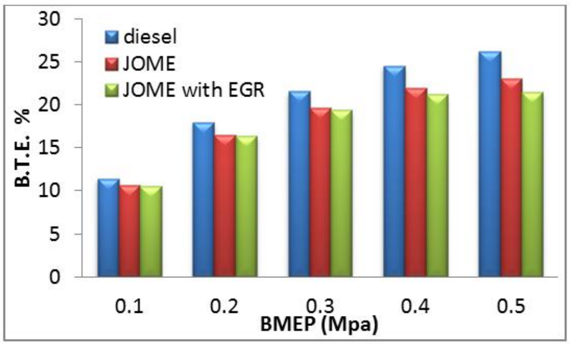

Fig. 3. B.T.E of Jatropha Biodiesel vs. BMEP.

3.3. CO Emission

Figure 4 presented the trend of Carbon monoxide (CO) emission with the BMEP. It was observed that it decrease with increase in load. This trend is different from the most of the researchers [36-38]. The similar trend was also observed by the few [39]. Jatropha Biodiesel showed an average reduction of 13.3 percent in CO emission.

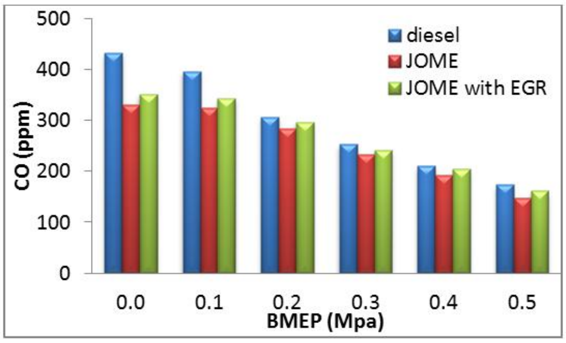

Fig. 4. CO Emission of Jatropha Biodiesel vs. BMEP.

This may be due to the presence of oxygen molecules in the Jatropha Biodiesel helping the complete combustion. EGR on Jatropha Biodiesel results in 5.9 percent increase in CO emission compared to Jatropha without EGR however reduction of 8.2 percent was observed compared to neat Diesel fuel. Increase of CO emission while using EGR may be due to the increase in fuel consumption reducing the air fuel ratio which in turn increases the CO Emission.

3.4. HC Emission

The variation of Hydrocarbon (HC) emission with the BMEP is presented in Figure 5. It can be observed that HC emission increases with the increase in load. Jatropha Biodiesel reduces an average 16.8 percent HC emission. This may be attributed to the favourable effect of Jatropha Biodiesel as an oxygenate fuel as discussed before. Use of EGR in Jatropha Biodiesel result in increased HC emission, may be due to the dilution effect of re-circulating exhaust gases, affecting the supply of fresh oxygen leading to incomplete combustion. Jatropha Biodiesel with EGR showed an average increase of 14.7 percent compared to Jatropha Biodiesel without EGR. However result showed an average reduction of 4.64 percent compared to neat diesel.

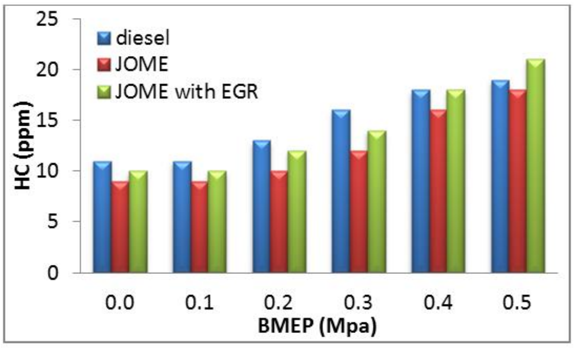

Fig. 5. HC Emission of Jatropha Biodiesel vs. BMEP.

3.5. NOx Emission

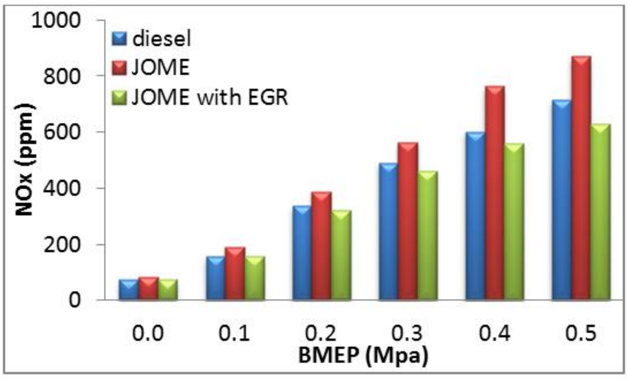

Fig. 6. NOx Emission of Jatropha Biodiesel vs. BMEP.

The variation of Nitrogen oxide (NOx) emission with the BMEP is presented in Figure 6. It can be observed from the figure that the NOx emission increases with the increase in load. Jatropha Biodiesel showed an average of 19.6 percent higher NOx Emission compared to diesel fuel. The increase of NOx formation may be attributed to higher oxygen molecules of Jatropha Biodiesel resulting in the increase of in-cylinder temperature and hence NOx. EGR leads to reduce the NOx emission. Recirculation of Exhaust gases containing water vapours and carbon dioxide results in the reduction of the in-cylinder temperature. Use of EGR in Jatropha Biodiesel showed an average of 19.85 percent reduction in NOx Emission compared to without EGR and 4.31 percent compared to neat Diesel fuel.

3.6. Smoke Emission

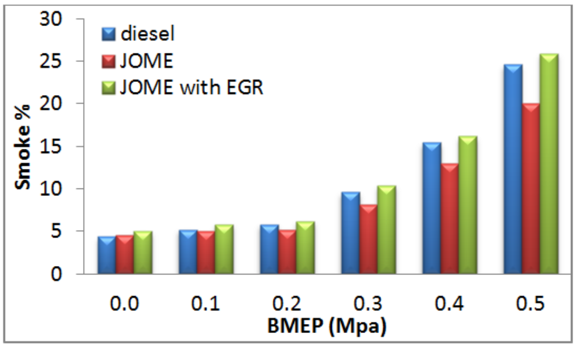

Fig. 7. Smoke Emission of Jatropha Biodiesel vs. BMEP.

Figure 7 shows the variation of Smoke emission with the BMEP. The results showed an increase in smoke emission with increase in load. Jatropha Biodiesel showed 9.75 percent reduction in smoke compared to diesel fuel. This may be due to the oxygen content of the biodiesel molecules, which enables more complete combustion even in regions of the combustion chamber with fuel-rich diffusion flames, and promotes the oxidation of the already formed soot [40, 41]. EGR results in the increase of smoke emission. The reason could be reduced oxygen availability, in the combustion chamber to premix with the fuel injected, and to oxidize the formed soot. The result showed an average increase of 20.8 percent in smoke emission compared to without EGR and 8.41 percent compared to neat diesel fuel.

4. Conclusion

The Experimental study was carried out to compare the performance and Emission parameters of a Diesel Engine using EGR, fuelled with Jatropha Biodiesel and neat Diesel. The major conclusions are as follows

- Engine was operated with Jatropha Biodiesel with the EGR without any problem.
- Jatropha Biodiesel can be potential alternative diesel engine fuel if used with the exhaust gas recirculation.
- The Drawback of increased NOx Emission with Jatropha Biodiesel was found to reduce by use of EGR.
- Use of Jatropha Biodiesel with EGR result in slight reduction in Brake thermal efficiency, Carbon monoxide, Unburned Hydrocarbon but a slight penalty on smoke emission compared to neat Diesel fuel.

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