# Experimental Investigation of a Diesel-Biodiesel Fuelled Compression Ignition Engine with Exhaust Gas Recirculation (EGR)

**Achuthanunni V, Baiju B**

***Abstract— Biodiesel is derived from vegetable oils or animal fats through transesterification process. There are many advantages of biodiesel but it is not so popular because of high NOx emission. In order to reduce NOx emission from the engine, it is necessary to keep peak combustion temperature under control. EGR technique is one of the method to reduce NOx emission as it enables lower flame temperature and oxygen concentration in combustion chamber. The main objective of this paper is to fabricate an exhaust gas recirculation (EGR) set up for the CI engine and produce biodiesel from sunflower oil then investigates the usage of biodiesel in the diesel engine without any engine modification. Experiments are conducted in a single cylinder, four-stroke diesel engine with 10 % EGR and without EGR. The result shows that 40% NOx emission is reduced by using EGR and the performance of biodiesel was found to be comparable with diesel at all loads.***

***Keywords— Biodiesel, EGR, Emission, $NO_X$.***

***Nomenclature—*** $M_{EGR}$ ***mass of gas re circulated (kg/s)***
$M_{TOTAL}$ ***mass of air intake (kg/s)***

## I. INTRODUCTION

Fossil fuels (i.e., petroleum, natural gas and coal), which meet most of the world's energy demand today, are being depleted rapidly. Also, their combustion products are causing global problems, such as the greenhouse effect, ozone layer depletion, acid rains and pollution, which are posing great danger for our environment, and eventually, for the total life on our planet. It is observed from the experiment that EGR is good technique to reduce all regulated emission from diesel engine but it gives good result when engine is operated with EGR using bio-diesel blend. It has shown that brake thermal efficiency for Bio-diesel blend is higher than base line data of diesel. Along with there is reduction in the emission of Hydrocarbon HC, CO, NOx & smoke when blends of bio diesel are operated with EGR, Pooja Ghodasara [1]. Rudolph Diesel, the father of diesel engine, demonstrated the first use of vegetable oil in compression ignition engine in 1910. He used peanut oil as fuel for his experimental engine, H.E. Saleh [4]. Biodiesel is a renewable fuel which is free from sulfur and aromatic compounds. Biodiesel does not overburden the environment with $CO_2$ emission as $CO_2$ from the atmosphere is absorbed by the vegetable oil crop during the photosynthesis process, while the plant is growing. Hence biodiesel offers net $CO_2$ advantage over conventional fuels. The use of biodiesel in diesel engines does not require any hardware modification, N. Saravanan [6]. The effect of cooled EGR with high ratio at full load on engine performance and emissions was examined.

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The results showed that EGR is an effective technique for reducing NOx emissions with JME fuel especially in light duty diesel engines. A better trade-off between HC, CO and NOx emissions can be attained within a limited EGR rate of 5–15% with very little economy penalty,ref. A. Tsolakis *et al*. [7].

## II. BIODIESEL PRODUCTION

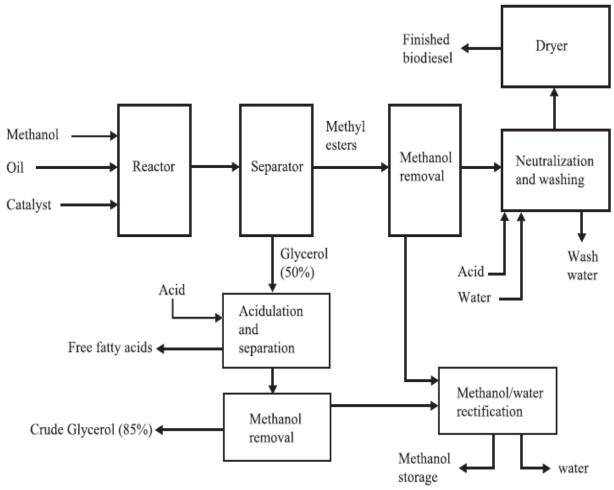


**Fig. 1: Block Diagram for Biodiesel Production**

### *A. Transesterification*

The fatty acid triglycerides themselves are esters of fatty acids and the chemical splitting up of the heavy molecules, giving rise to simpler esters, is known as transesterification. The triglycerides are reacted with a suitable alcohol (Methyl, Ethyl, or others) in the presence of a catalyst under a controlled temperature for a given length of time. The final products are alkyl esters and glycerin. The alkyl esters, having favorable properties as fuels for use in CI engines, are the main product and the glycerin, is a byproduct. The chemical reaction of the triglyceride with methyl alcohol is shown in figure. 2. It can be seen from the reaction that one mole of the heavy triglyceride and three moles of methyl alcohol yields one mole of glycerol and three moles of lighter fatty methyl esters. Without the use of a catalyst the reactions would be very slow and also incomplete. A temperature of 60°C to 70°C would be needed for the reactions to become effective. Also a vigorous agitation of the reactants would be needed and so a mechanized stirrer in the reaction vessel becomes necessary. Various catalysts can be used. The most common are the the alkalies, like NaOH and KOH. For transesterification any alcohol can be used. The most popular is methyl alcohol.



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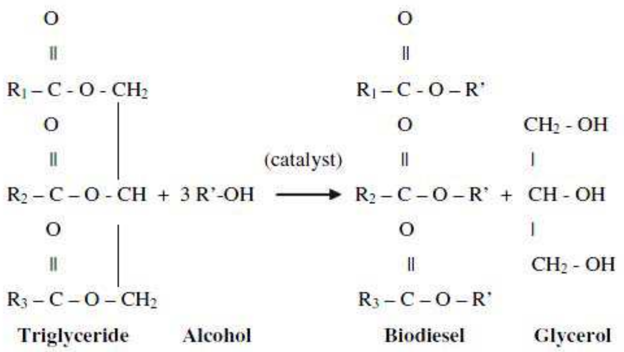


**Fig. 2: Stoichiometric Transesterification Reaction**

### *B. Procedure*

- Sunflower oil is taken as the oil, methanol as the alcohol and potassium hydroxide (KOH) as catalyst.
- Molar ratio between alcohol and oil used was 6:1, whereas catalyst amount was 1% of oil's weight.
- The catalyst was dissolved in methanol by stirring in a small beaker.
- About 1 liter of oil is taken in a beaker and is heated. When the temperature reaches 65$^{o}$C, the alcohol-catalyst mixture was added into the oil and the final mixture was stirred for 3 hours at 65$^{o}$C.

**Fig. 3: Transesterification Setup**

- After the reaction glycerin layer was separated in a separating funnel.


**Fig. 4: Biodiesel Separator**

- The ester layer was washed with warm water three times.
- After the final washing, the ester was subjected to heating above 100 $^{o}$C to remove moisture.

## III. EXHAUST GAS RECIRCULATION SYSTEM

EGR is a useful technique for reducing NOx formation in the combustion chamber of C.I. engines. Figure 5 shows the arrangement of exhaust gas recirculation (EGR) system. The principle of EGR is to re circulate about 10% to 30% of the exhaust gases back into the inlet manifold where it mixes with the fresh air and this will reduces the quantity of $O_2$ available for combustion. This reduces the $O_2$ concentration and dilutes the intake charge, and reduces the peak combustion temperature inside the combustion chamber which will simultaneously reduce the NOx formation. It should be noted that most of the NOx emission occurs during lean mixture limits when exhaust gas recirculation is least effective. The exhaust gas which is sent into the combustion chamber has to be cooled so that the volumetric efficiency of the engine can be increased. EGR ratio is defined as the ratio of mass of recycled gases to the mass of engine intake. EGR is the most efficient and widely used system to control the formation of oxides of nitrogen inside the combustion chamber of IC engine. The exhaust gas for recirculation is taken through an orifice and passed through control valves for regulation of the quantity of recirculation.

$$\%\ EGR = \frac{M_{EGR}}{M_{TOTAL}} \times 100 \qquad (1)$$


**Fig. 5: Exhaust Gas Recirculation Setup**

## IV. EXPERIMENTAL SETUP

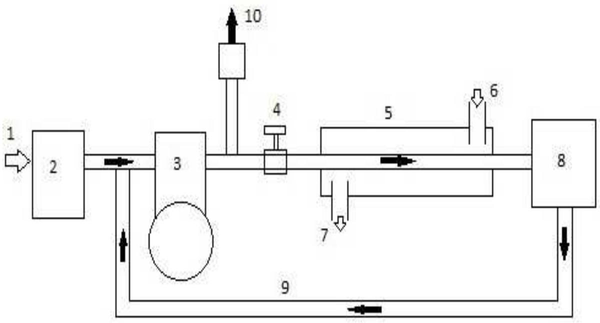


**Fig. 6: Block Diagram of Experimental Setup**



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| | |
|---|---|
| 1. Air inlet | 2. Inlet air orifice box |
| 3. Test engine | 4. EGR control valve |
| 5. Heat exchanger | 6. Water inlet |
| 7. Water outlet | 8.EGR orifice meter |
| 9. EGR pipe | 10.Exhaust gas outlet |

**Table 1: Specification of Diesel Engine**

| Parameters | Specification |
|---|---|
| Engine Make | Kirloskar |
| Number of cylinders | One |
| Bore (mm) | 85 |
| Stroke (mm) | 110 |
| Capacity ($cm^3$) | 624 |
| Injection system | Direct injection |
| Maximum power (BHP) | 10 |
| Rated speed (RPM) | 1500 |
| Cooling system | Water |

The engine used for the experimental work is a single cylinder, four stroke, water cooled compression ignition engine. The experimental setup is shown in figure.6. An orifice box is connected to the inlet manifold and the air mass flow rate is measured using the U tube manometer connected to the orifice box. The EGR system consists of a piping system taken from the engine exhaust pipe, an orifice meter to measure the flow rate of the exhaust gases and a control valve. The amount of exhaust gas recycling into the inlet manifold is controlled by means of a valves, connecting the exhaust line and the inlet manifold. The re circulated exhaust gas flows through another orifice meter with manometer for measuring the flow rate, before mixing with the fresh air. Cold EGR is attained by cooling the re circulated exhaust gas. The exhaust gas recirculation line is connected to a counter flow heat exchanger having water as the cold fluid. The probe of exhaust gas analyzer is inserted into the exhaust pipe for emission measurement. The engine is loaded using an electrical dynamometer.

## V. RESULT & DISCUSSION

In this experiment performance and emission characteristics of engine are compared using diesel and diesel-biodiesel blends at 10% EGR rate.

### *A. Brake Thermal Efficiency*

From the figure 7 it is observed that thermal efficiency improved with increasing concentration of biodiesel in blend. Also the same trend was observed by Pooja Ghodasara [1]. This is due to improved thermal efficiency observed with oxygenated fuel. B20 produced the maximum brake thermal efficiency among the biodiesel blends. Full load brake thermal efficiency of 18.91% was obtained for diesel without EGR whereas it was 15% for B10 and 15.74% for B20 biodiesel blends without EGR. Brake thermal efficiency at 40% load was also comparable for diesel and bio diesel.

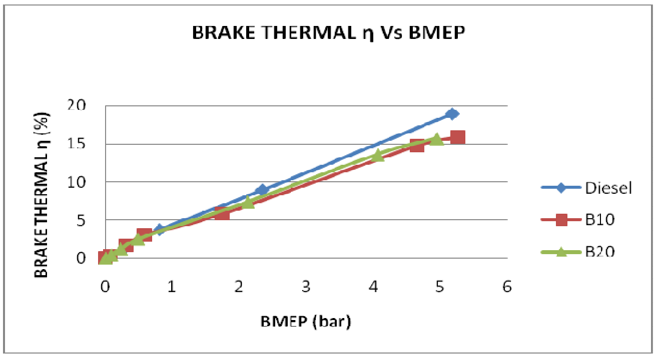


**Fig. 7: Brake Thermal Efficiency Vs Brake means Effective Pressure**

### *B. Specific Fuel Consumption*

For diesel and bio diesel, the variation of specific fuel consumption with brake power is shown in figure 8. Specific fuel consumption and total fuel consumption of diesel-biodiesel blend is higher than diesel at full load this is due to lower calorific values, higher viscosity and density. Specific fuel consumption without EGR, under full load was found to be 0.4327 kg/kWhr for diesel and 0.5138 kg/kWhr for for B10 and 0.519 kg/kWhr for B20 biodiesel blends.

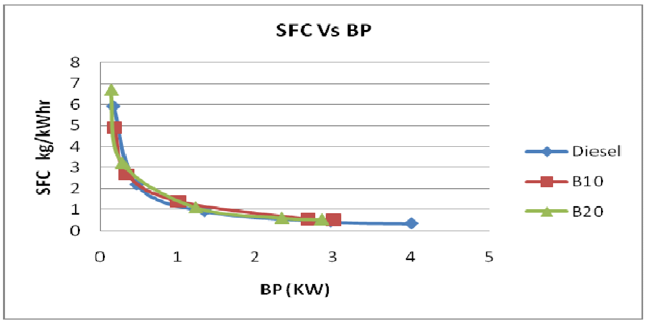


**Fig. 8: Specific Fuel Consumption Vs Brake Power**

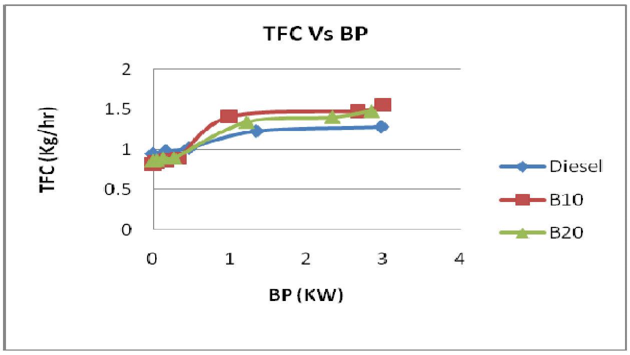


**Fig. 9: Total Fuel Consumption Vs Brake Power**

### *C. Oxides of Nitrogen*

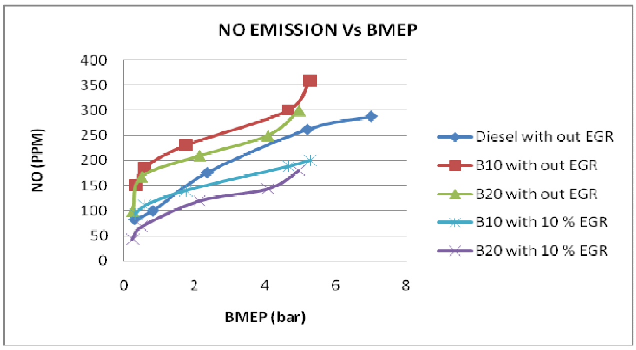


**Fig. 10: NO Emission Vs Brake means Effective Pressure**



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Figures 10 and 11 indicate the variation of nitrogen oxide with Brake mean effective pressure for diesel and diesel-biodiesel blends with 10 % EGR and without EGR. The reduction in NOx at higher load is higher due to lack of oxygen concentration and decreased flame temperature. Agarwal *et al.* [9] observed the main advantage of EGR in reducing NOx emissions from diesel engine. NO emission value was found to be 288 ppm for diesel and 300 ppm for 10% biodiesel blend without EGR at full load condition. This was due to peak combustion temperature inside the cylinder. With increases in EGR level, the NO value gets reduced. With 10% EGR, NO levels were 150 ppm for diesel and 180 ppm for biodiesel.

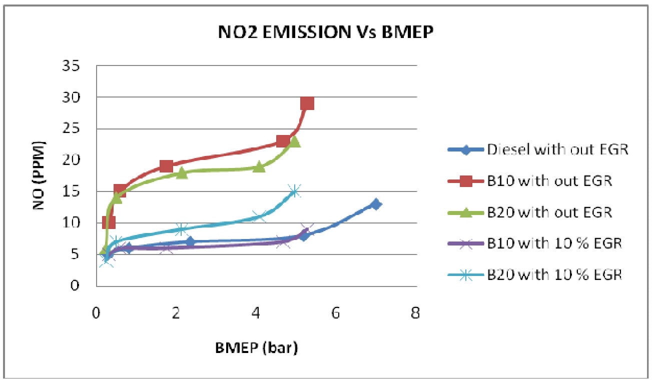


**Fig. 11: Nitrogen Dioxide Emission Vs Brake means Effective Pressure**

## VI. CONCLUSION

Biodiesel is an oxygenated fuel that undergoes improved combustion in the engine due to the presence of molecular oxygen but leads to higher NOx emissions. In the experiment higher NOx emissions is effectively controlled by 10% exhaust gas recirculation. Recycled exhaust gas lowers the oxygen concentration in the combustion chamber and increases the specific heat of intake charge which results in lower flame temperature and reduction in NOx formation. Brake thermal efficiency of biodiesel is found to be comparable with diesel at all loads. From the experiment, it is found that B20 has better performance compare to other biodiesel blends. The present experimental analysis on a single cylinder diesel engine with diesel and biodiesel blend at10% EGR has proved minimized pollution and improved performance. There is an average reduction of 40% NOx emission is obtained by 10% EGR.

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