

## Reduction of NO<sub>x</sub> Emission in Bio Diesel Engine with Exhaust Gas Recirculation and Magnetic Fuel Conditioning

P. Govindasamy and S. Dhandapani

**Abstract**— The depletion of fossil fuels and increase in the emission levels has caused a concern globally. An eco-friendly alternate was required to fulfill the growing demand. Bio fuels have proved to be the best alternative. The overall performance and emission tests have given good results except for the NO<sub>x</sub> component of the emission. This experimental work focuses on the reduction of this component to a great extent with the implementation of techniques called Exhaust Gas Recirculation and Magnetic Fuel Conditioning

**Keywords**— Exhaust gas recirculation, nitrogen oxides, emission, high gauss magnet.

### 1. INTRODUCTION

Today the world has realized that fossil diesel stock will almost come to an end within a few decades and if alternatives to these are found out, our vehicles would soon have a new eco friendly fuel to be used in the future. Bio diesel, due to its biodegradable nature, and essentially no sulphur and aromatic contents, offers to reduce particulate and toxic emissions [1]. Bio diesel when mixed with diesel fuel in small quantities also seems to improve the fuel lubricity, extend engine life and reduce fuel consumption [2]-[6].

Jatropha oil is used as an alternative to diesel. This oil is chosen because it has properties "Table 1" similar to that of diesel and mixing with the petroleum diesel would be really easy. Due to higher cetane number and lubricating properties, this fuel gives good performance with any diesel engine [2]. While analyzing the emissions in Jatropha oil and comparing with that of diesel, all the components in the emission got reduced drastically except NO<sub>x</sub>. This paper mainly focuses on the methodology of reducing the emission of NO<sub>x</sub> using the techniques called Exhaust Gas Recirculation and Magnetic Fuel Conditioning [7]-[9].

The emissions in general like CO, HC etc., can be reduced by fuel magnetization. The fuel is polarized to enhance the mixing of the air and fuel thereby producing a complete combustion. The idea that magnetizing hydrocarbon fuel can improve combustion and engine efficiency has been around since at least the 1930s.

In 1936, Chinese fishermen are said to have been applying magnets to engine fuel lines in fishing boats in order to improve fuel economy [10] & [11].

A report entitled, "Investigation of the effects of the

use of Magno-Flo magnets on diesel engines", by Dr Joe Cheung, of the Bolton Institute School of Engineering, shows improvements from 5% to 10% in fuel consumption in an engine under load.

**Table 1. Properties of Jatropha Oil**

Parameter	Jatropha Bio diesel
Density (g cm <sup>-3</sup> at 20°C)	0.879
Flash point (°C)	191
Fire point (°C)	207
Cetane number	57-62
Viscosity(mm <sup>2</sup> /s at 40°C)	4.20
Calorific value (MJ/L)	32.80

In order to study magnetic field effect on fuel oil, kinematic viscosities of fuel oils were measured. From the results of measurement, the analysis was carried out to clarify whether magnetic effect on fuel oils exists or not. Magnetic effects on fuel oils were significant over 95% and especially significant when the magnetic field of 2500 or 9500 gauss was used

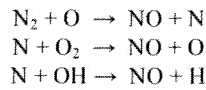
### 2. MECHANISM OF NO<sub>x</sub> FORMATION

A major hurdle in understanding the mechanism of formation and controlling its emission is that combustion is highly heterogeneous and transient in diesel engines. NO is formed during the post flame combustion process in a high temperature region. The most widely accepted mechanism was suggested by Zeldovich. The principal source of NO formation is the oxidation of the nitrogen present in atmospheric air.

The nitric oxide formation chain reactions are initiated by atomic oxygen, which forms from the dissociation of oxygen molecules at the high temperatures reached during the combustion process [8]. The principal reactions governing the formation of NO from molecular nitrogen are

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Formation of  $\text{NO}_x$  is almost absent at temperatures below 2000 K. Hence any technique, that can keep the instantaneous local temperature in the combustion chamber below 2000 K, will be able to reduce  $\text{NO}_x$  formation.

### 3. EGR: $\text{NO}_x$ REDUCTION TECHNIQUE

Exhaust Gas Recirculation is a process developed to reduce a type of harmful air pollution. It is primarily used as an emissions control device on fuel driven engines. EGR systems control the amount of  $\text{NO}_x$  expelled from the exhaust of an engine by controlling the temperature of the combustion chamber. Specifically, under heavy engine loads, the internal temperature becomes ideal to create oxides of nitrogen.

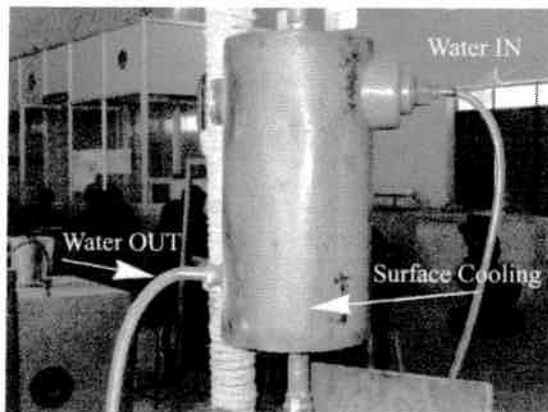


Fig. 1. Exhaust Gas Recirculation System

Re introducing an inert gas into the combustion process to keep the temperatures down - mainly the carbon dioxide, which the engine already expels, does reducing  $\text{NO}_x$ . The system is mechanically simple as it is nothing more than a valve, which taps the exhaust gasses and pumps it into the engines intake manifold "Figure 1".

### 4. MAGNETIC FUEL CONDITIONING SYSTEM

The magnetic fuel conditioning system is fabricated with a stand containing a fuel tank to hold the charged fuel. It also consists of a radiator core, 9500 Gauss "Figure 2" ferrite permanent magnet "Figure 3", a fuel pump and some piping. The flow is continuously maintained with the pump for circulation "Figure 4" of the fuel for polarizing it [12]-[14].

These devices are external online installations without cutting or modifying the fuel pipes and the magnetic energy generated through the monopole is rendered concentric and exactly perpendicular to the flow of the fuel "Figure 5"

The most important factors in the magnetic fuel conditioning is the magnetic field intensity and the collimation of the magnetic lines of flux [15]. The intensity of the magnetic field is far superior to that generated by regular permanent magnets and the

collimation of the magnetic fields renders the magnetic lines of flux exactly parallel to each other at extremely high densities (to the order of millions of lines of flux per sq. cm.) [16].

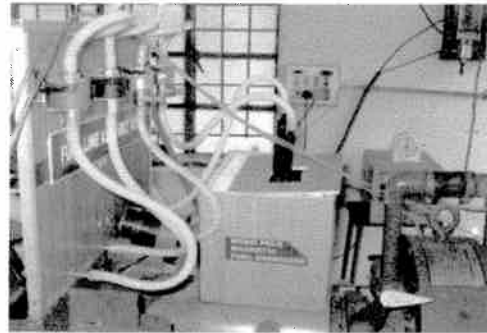
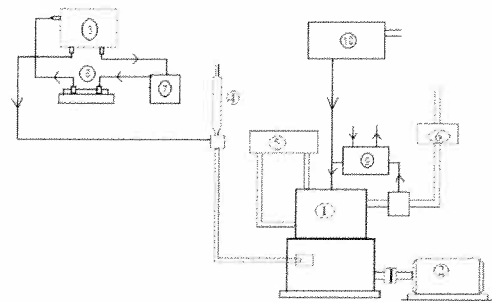


Fig. 2. Experimental Setup of Fuel Conditioner



Fig. 3. Neodymium Magnet (9500 Gauss)



- |                 |                    |
|-----------------|--------------------|
| 1 Engine        | 6 Gas Analyzer     |
| 2 Alternator    | 7 Fuel pump        |
| 3 Fuel Tank     | 8 Permanent Magnet |
| 4 Metering tube | 9 EGR              |
| 5 Cooling water | 10 Air box         |

Fig. 4. Schematic Diagram of Experimental Setup

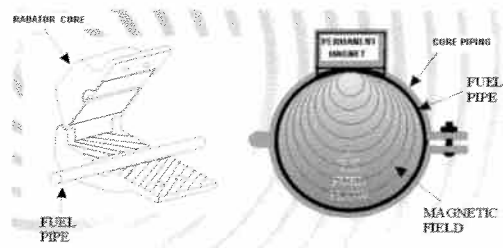


Fig. 5. Functional View of Magnetic Fuel Conditioner

## 5. EXPERIMENTAL PROCEDURE

The following steps were followed in approaching the above said problem of emissions and scope for Jatropa oil in the future as an alternate fuel.

1. Single cylinder, four stroke, water cooled, electrically loaded engine with AVL five gas analyzer and AVL smoke meter have been used for experiments "Figures 4 & 6".
2. The Jatropa oil was procured and blends of 50% and 100% bio diesel were prepared for the testing purpose.
3. A permanent magnet of 2500 Gauss was used in the fuel line, which was used to energize the fuel before injection. Another conditioning magnet of 9500 Gauss was also used in case of bio diesel "Figure 3".
4. EGR system was fabricated with heat exchanger having cooling system to cool the exhaust gas before recirculation "Figure 1".
5. Engine modification for EGR was made.
6. The performance tests and the heat balance tests have been carried out to compare the various blends for the following cases.
  - Without any engine modification.
  - With implementation of EGR.
  - Without the fuel conditioning setup.
  - With the fuel conditioning setup
7. A comparison study in terms of performance of the blends and emissions is also carried out.



Fig. 6. AVL Make Five Gas Analyzer & Smoke Meter

## 6. CONCLUSIONS

From the experimental results the following conclusions were made:

- The mechanical efficiency of the engine while using Bio diesel is more than the conventional petroleum diesel "Figure 7". When the percentage of Bio diesel increases the mechanical efficiency also increases simultaneously. With EGR, the mechanical efficiency was found to increase by 13%.
- No considerable change in the value of the torque was noticed. The torque remained almost the same for all the blends irrespective of EGR.

- There was no considerable change in the value of the brake mean effective pressure though the value of the 50% blend was closer when compared to other blends. The energized blends were also closer to diesel.
- There was a slight decrease in indicated thermal efficiency while using EGR and with various blends of Bio diesel. However, the presence of the magnetic fuel conditioner has increased the values by about 5%.
- Other performance characteristics of the diesel engine running with Bio diesel almost remained same with the implementation of EGR and magnetic fuel conditioning.
- The emission of  $\text{NO}_x$  came down drastically with the use of EGR "Figure 8". It was zero in some cases. The CO and HC values got reduced with the implementation of the magnetic fuel conditioning technique "Figures 9 & 10".

With a magnetic field we can increase the internal energy of the fuel, to cause specific changes at a molecular level. Increasing the internal energy means molecules fly apart easier, join with oxygen easier and ignite well to obtain easier combustion.

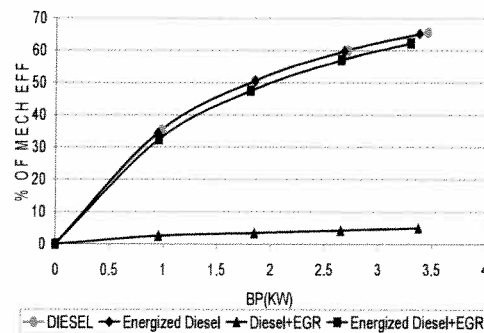


Fig. 7. Variation of Mechanical Efficiency with Brake Power

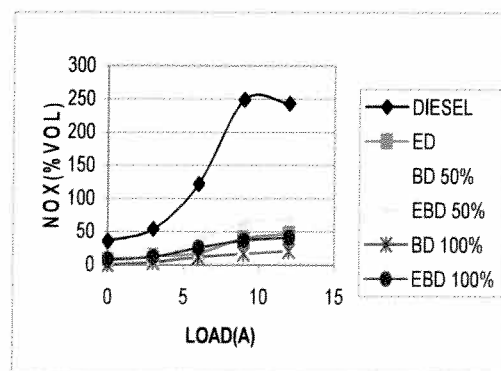


Fig. 8. Variation of NOx with Load

The resultant conditioned fuel is magnetized to burn more completely, producing higher engine output, better fuel economy, more power and most importantly reduces the amount of hydrocarbons and carbon monoxide in the exhaust.

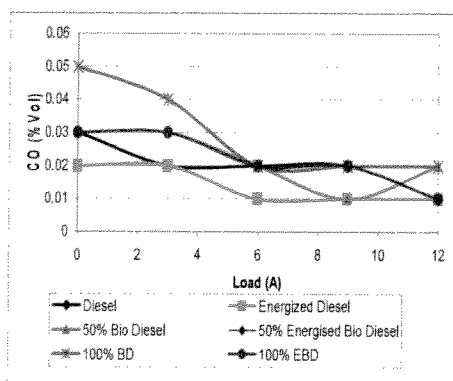


Fig. 9. Variation of CO with Load

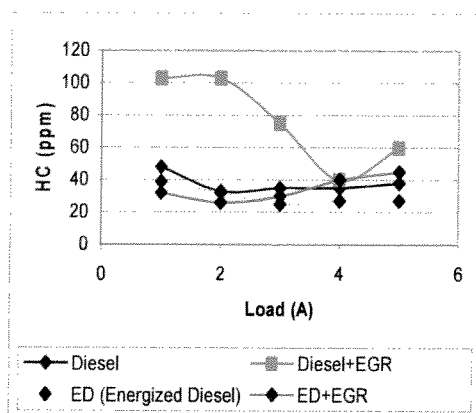


Fig. 10. Variation of HC with Load

Finally, it is concluded that the use of EGR is more effective with the bio diesel and the magnetic fuel conditioning system for the diesel for achieving improved performance of the engine

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