Performance & Emission Characteristics of Diesel Engine fueled with Bio-Diesel along with Additives (NM, MTBE)

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Abstract. The significant quantity of power is expensive in transportation segment & industrial sector and also a critical command in meeting through CI engine in all over the world due to their greater performance as contrast to the conventional diesel fuels. However, there was a tremendous alarm regarding the crude oil products which are going to be depleted in near future. So, in this connection it is necessary to reach, the suitable fuels other than the fossil fuels and also on the other hand it is mandatory to control the expense of the both fuels. In this work an attempt is to be made to investigate the commercial use of suitable and non-toxic additives in order to improve the performance of an engine without sacrificing the functionality parameters. The main concern of this work is to utilize the maximum effective way to control the asserted parameters like emissions and combustion characteristics. This investigation carried out on a diesel engine fuelled with B100 (jatropha) with two additives, Nitro methane (Nm) and Methyl Tetra Butyl Ether (MTBE) are tested in kirloskar computerized diesel engine. Jatropha bio-diesel is a biodegradable, non-toxic, renewable fuel, environment friendly and do not build on globalwarming. Additives selected are based on the biodiesel characteristics, and economic feasibility. Additive MTBE is used for oxygenated and the other additive Nm is used as cetane booster.

Key words: Additives, Transestification, Bio-diesel, CI engine, Emissions

1. Introduction

Bio-diesel fuels can supply a viable alternative in the energy scenario of the earth power crisis. This complex condition in the field of energy requirements has resulted from the tremendous increase in population, enhanced technological advancement, better living standards and industrialization. On a daily basis, the price of crude oil keeps increasing and fluctuating. Over the last decade, the fluctuations in energy prices have been very important. Over the 1990s, environmental approvals have increased dramatically in the world. Global environmental pollution impacts such as greenhouse effect, acid rain, ozone depletion, climate change etc have been caused by increased use of fossil fuels. The above considerations include the production and commercialization of bio-origin alternatives to fossil fuels. The authors have been working on biodiesel due to their increasing understanding and attention in non-conventional bioenergy sources and fuels. The authors have been used diesel with Jatropha curcas (Ratabgyit), Pongamia Pinnata (Karanji) and now in this research paper we used Jetropha bio-fuel. We have also make use of Nitromethane (NM) and Methyl Tetra Butyl Ether (MTBE) as additives [1,2].
1.1 Fuel additives

Fuel additives are substances developed to increase the quality and performance of the fuels used in automobiles. In certain situations, the distributor introduces the additive into the petrol itself; at some other times, the fuel additive is marketed as a separate commodity that can be used by customers to boost or preserve their engine performance. There are also some advantages due to fuel additives being used. One of the key advantage is engine performance. With few fuel oil additives, the substance is stated to improve the gasoline octane rate, allowing the engine with greater power from the same volume of fuel. The final outcome is the potential to drive quicker on fuel blended with additives than would otherwise be feasible. Another common advantage cited by promoters of fuel additives is engine maintenance. With these kinds of improved materials, the concentration is on removing the accumulation of sludge and other contaminants in diverse locations of the engine. Because there is less buildup in the lines and many of the moving parts on the motor, less stress is applied on the engine throughout operation, ultimately extending the life of the automobile [3, 4]

2. Literature review

The outcome of biodiesel on NOx emissions were reviewed by Hoekman and Robbins [5]. The use of biodiesel normally find out to minimize exhaust emissions of carbon monoxide (CO), unburnt hydrocarbons (HC), and particulate matter (PM) relative to traditional diesel fuel, but to increase emissions of nitrogen oxides (NOx). Several aspects associated to fuel compositions and engine control measures are important in modern diesel engines, but no single theory offers a honest description about the exhaust emissions of biodiesel and its effects on NOx emissions at all conditions. But some data is supporting these effects with retarding the fuel injection timing, adiabatic flame temperature (AFT), and combustion process are all playing a important role. The NOx emissions of the biodiesel will greatly reduced by altering the engine settings like reducing the injection timing, EGR circulation etc. he also explained that, the modern engine designs are encouraging the usage of biodiesel without changing the engine setup and greatly reducing the NOx effect. But still there are some cases where need to improve in the exhaust gas emissions.

3. Procedure of experiment

Experiments are performed on a Kirloskar AV-1 stationary CI engine at IC Engines laboratory Department of Mechanical Engineering.

3.1. Experimentation

Initially the experiment is conducted with conventional diesel fuel (for noting down the standard data of the engine to compare) and next engine will run with Jatropha bio-diesel, and then bio-diesel with additives. The performance of the engine is calibrated in terms of brake specific fuel consumption, brake thermal efficiency, mechanical efficiency, exhaust gas emission of the engine are evaluated.

3.2. Exhaust gas analyzer

The gas analyzer measures, Oxygen (O2), Hydrocarbons (HC), Carbon Dioxide (CO2), Carbon Monoxide (CO), and Nitrogen Oxide (NOx) at the exhaust of the engine.

3.3. Additives selection

The additive selection was done for oxidizing the fuel dependent on toxicity, additive solubility, economic feasibility, fuel blending property, viscosity of the fuel, flash point of bio-diesel & water partitioning of the additive. The additives containing more number of oxygen materials like ethylene, diethyl ether, propylene carbonate are available in the market. Based on properties of selected bio-diesel,
economic feasibility, toxicity, and blending capacity of the additive methyl tetra butyl ether (MTBE) is one additive selected and the other is nitro methane (NM) which is a cetane booster.

Table 3.1. Specifications of Exhaust Gas Analyzer

| Sl. NO | Specifications        | Gas Analyzer |
|--------|----------------------|--------------|
| 1      | Warm up time         | 7 minutes    |
| 2      | Operating Temperature| 5 to 45°C    |
| 3      | Storage Temperature  | 0 to 50°C    |
| 4      | Inclination          | 0 to 90°     |
| 5      | Dimension (w*d*h)    | 270 mm * 320 mm * 85 mm |

Table 3.2. Additives characteristics

| Properties              | MTBE      | Nitro methane |
|-------------------------|-----------|---------------|
| Density (kg/m³)         | 740.4     | 1137.1        |
| Calorific value (MJ/kg) | 40.72     | 11.3          |
| Molar mass (g/mol)      | 88.15     | 61.04         |
| Flash point (°C)        | -10       | 35            |
| Boiling point (°C)      | 55.2      | 100-103       |

3.4. Methodology

The engine is fed with conventional diesel fuel and started at an injection pressure of 180 bar and working characteristics, emission parameters are noted down. The noted results of conventional diesel are standard values and selected for comparison of performance and emission characteristics of selected bio-diesel blends with additives. The test rig then fed with jetropha bio-diesel with 1% MTBE additive at an injection pressure of 180 bar corresponding results are noted down, with same blend we run the engine at injection pressure of 200 bar and noted down the both performance and emission characteristics. We repeated the procedure for additive nitro methane at both 180 and 200 bar injection pressure.

4. Performance and Emissions Results

The emission and performance characteristics were performed on kirloskar Av-1 4-S, 1- cylinder using water as coolant, direct injection, constant speed engine mostly used in farming fields. The diesel engine loading by eddy current dynamometer operated with electrical device. The performance and emission characteristics were investigated with jetropha bio-diesel plus additives.

4.1. Brake specific fuel consumption (bsfc)

Figure 4.1. Shows break specific fuel consumption (bsfc) variations for all the fuels with change in brake power (BP)
At 1 kW bp, break specific fuel consumption is maximum for all biodiesel and diesel. Than we can observe the continuous decrease in break specific fuel consumption with increase in bp. But break specific fuel consumption, in the case of jetropha biodiesel remains more than the conventional diesel w.r.t increased brake power in the engine. It is because of lower energy content of jetropha biodiesel. At initial BP values brake specific fuel consumption of jetropha+1% Nm is less than diesel. Whereas at final conditions break specific fuel consumption of biodiesels almost 11.9% greater than that of conventional diesel.

4.2. Mechanical efficiency

Change in mechanical efficiency of biodiesel+additives, and diesel with respect to change in brake power is shown in the fig 4.2. Initially mechanical efficiency of diesel and biodiesel+additives is same. As break power increases, mechanical efficiency increases because mechanical efficiency is directly proportional to break power. But as load on the engine increases the brake power increases. At full load, jetropha+1% Nm biodiesel is 3.5% more than that of the conventional diesel. The Mechanical efficiency of jetropha+1% Nm and jetropha+1% MTBE is nearly same.
4.3.  Brake Thermal efficiency (BTE)
Figure 4.3. Illustrate change in BTE of biodiesel and diesel w.r.t. change in brake power as shown below. At initial brake power condition, BTE of biodiesels and ordinary diesel is same. As the brake power value of engine increases, BTE value increases because BTE is function of BP. At initial load conditions, the BTE of jetropha+1% MTBE (200 bar) is greater than conventional diesel because calorific value of jetropha biodiesel less than that of diesel.

![BP Vs Brake thermal efficiency](image)

**Figure 4.3. brake thermal efficiency Vs brake power**

4.4  Emissions
Exhaust emissions of unburned hydrocarbons, nitrogen oxide, and carbon monoxide were analyzed & the results are given below. In general nitrogen oxides will form at very high temperatures, whereas the unburned hydrocarbons and carbon monoxides are the products of improper combustion.

4.4.1.  Hydrocarbons
Figure 4.4.1. Shows the change in the amount of unburnt HC with variation of brake power (in kw.) at 17.5 compression ratio. Initially diesel emits more amount of unburnt hydrocarbons than the all other biodiesel+1% additives. At brake power around 1 kW diesel emits less unburnt HC along with jetropha+1% Nm additive. At maximum BP value all jetropha+1% additives emits less unburned hydrocarbons than the ordinary diesel. These biodiesel+1% additives emits around 50% less HC than the diesel. The higher cetane number of fuel decreases in HC emissions due to increased temperature of burnt gases in biodiesel helps in preventing in condensation of hydrocarbons thus reducing un-brunt HC emissions.
Figure 4.4.1. HC Vs BP

4.4.2. Nitrogen oxides

Figure 4.4.2. Illustrates that, variation in the amount of NO\textsubscript{x} (in ppm) w.r.t. change in brake power (in kw.) at 17.5 compression ratio. At initial brake power, all biodiesel+1% additives emits less amount of NO\textsubscript{x} than the diesel. The brake power of the engine increases as the load increases and NO\textsubscript{x} emissions increases because, temperature of combust products increases, at very elevated temperatures greater amounts of NO\textsubscript{x} liberates. But diesel emits comparatively more NO\textsubscript{x} in the exhaust at maximum brake power. Jetropha+1% additives emits around 30% less NO\textsubscript{x} in the exhaust. The addition of 1% additives decreased the considerable amount of NO\textsubscript{x} in the exhaust.

Figure 4.4.2. Variations in quantity of NO\textsubscript{x} with change in brake power

5. Conclusions

Regarding to this experimental investigation carried out on CI diesel engine fuelled with jatroha (B100+1%) biodiesel with additives are analyzed the effect of additives on engine performance and exhaust emissions. These test results are contrasted with conventional diesel. The following conclusions are drawn.

- Fuel B100+1% Nm produces 1.94% of more BP than the diesel. This is due to higher cetane number for B100+1% Nm which reduces the ignition delay leads to complete combustion liberates more power.
As the engine load increases, the mechanical efficiency of bio-fuel B100+1% Nm is 4.02%, and bio-fuel B100+1% MTBE is 3.15% more than that of conventional diesel fuel.

These biodiesel+1% additives emits around 80% less HC than the diesel. The higher cetane number of fuel decreases in HC emissions due to increased temperature of burnt gases in biodiesel helps in preventing in condensation of hydrocarbons thus reducing un-brunt HC emissions.

As engine load increases it increases the brake power and also NOx exhaust enhanced because the temperature in the engine cylinder increases, at higher temperature more amount of NOx will liberate. But diesel emits comparatively more NOx in the exhaust at maximum brake power. Jetropha+1% additives emits around 30% less NOx in the exhaust.

B100+1% additives shows that, the exhaust emissions are lesser than that of conventional diesel irrespective of loading conditions.

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