Experimental Investigation of CI Engine Performance by Nano Additive in Biofuel

S.Manibharathi, B.Annadurai, R.Chandraprakash

Abstract—**The effect of Nano additives [rhodium oxides (Rh_2O_3)] on the performance and emission characteristics of pongamia bio diesel in a single cylinder direct injection diesel engine. The Nano additives (rhodium oxides) are prepared by ball milling process .the particles size obtained in the range of 100nm. The particle size is characterized by using scanning electron microscope (SEM). The Nano particles were dispersed in the biodiesel with the help of magnetic stirrer with the optimized surfactant concentration. The Nano additive was added with pongamia oil to improve an anti were behavior in engine. The reduction of specific energy consumption at part load condition and full load condition by adding Nano additives. Nano additives reduce carbon deposit and wear of diesel engine. A rhodium oxide acts as oxygen which improves performance and reduces the emission. The addition of Nano additives in fuel it reduces NO_x emission up to 37% when compare with diesel .it also reduces the unburnt hydrocarbon (UBHC) up to 45%. Nano particles are reduces the energy consumption and improves the thermal efficiency, during combustion the additives release the energy to the fuel.**

Index Terms—**Nano particles, Bio diesel, Fuel additive, Rhodium oxide.**

I. INTRODUCTION

The increasing price of crude oil and increasing demand of fuels in the world, with the help of bioenergy, it has provided an effective way to fight against the problem and the influence on environment.

Biodiesel is an eco-friendly renewable alternative fuel of diesel, it is made by trans esterification of vegetable oils and animal fat[1].The main feedstock for biodiesel production in India is non-edible oils obtained from plant species such as Jatropha (Jatropha curcas), pongamia (pongamia pinnata)and polanga (Calophyllum in ophyllum) due to the high cost of edible oils . The natural distribution of Pongamia is along coasts and river banks in India and also in humid tropical lowlands. Pongamia oil available in large quantity is a good feedstock for biodiesel synthesis with production of 200 million tonnes of oil per year in India [1].The seed contains an average of 28-34% of oil with high percentage of polyunsaturated fatty acids. Pongamia methyl ester has the advantages of having higher Cetane number, oxygen content and it is clean. Biodiesel having certain drawbacks such as oil thickening at higher temperature, higher emission and lower performance.

The problems associated with the biodiesel, use of chemical substance like fuel additives derived from organic and inorganic metal are uses. A Nano additive generally improves the combustion efficiency and reduces the emission. Metallic based compounds, such as manganese, copper rhodium, iron, copper and platinum etc.., it have been used as combustion catalyst for hydrocarbon fuel. Recent advance in nano technology enables production, control and characterization of Nano scale energetic materials. Main advantage of using nano particle is its size, because the particles are micron sized so there is no chance for clogging and fuel injector.

The effects of using vegetable oil based additive combined with metal based additive on exhaust emission of diesel engine fuelled with biodiesel [4]. Additive helps engine to burn fuel better and excess air reduce the CO content. The temperature inside the cylinder during combustion was reduced due to the presence of additive in the blended furl. Hence it reduces NO_x emission. Study to improve properties of ignition in diesel fuel and investigated the influence of size and Quantity of Al and Al_2O_3 nano particles in a diesel fuel [5]. Finally it was concluded that the potential of reducing the evaporation time of droplets by the increasing the heat and mass transfer properties of diesel fuel. It was inferred that it shortens the ignition delay and probability to increase the ignition of diesel.

TABLE 1 FUEL PROPERTIES

Properties	Diesel	Biodiesel
Density@ $15^0C(Kg/m^3)$	810-860	870-895
Viscosity (cSt)@40^0C	2-3.5	3.5-5.5
Calorific Value MJ/Kg	42.5	40
Flash Point ^0C	75	145
Fire point ^0C	80	160
Cetane Number	40-50	45-65
Carbon (%)	86.8	76.5
Hydrogen (%)	13.1	12
Oxygen (%)	-	11.3

In the present investigation, Biodiesel was produced from Pongamia oil and investigation on performance and emission characteristics were evaluated using compression ignition engine and also investigated the addition of nano additive on

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biodiesel effects. The properties of biodiesel are shown in table.1.

II. NANO PARTICLES PREPARATION

Nano Rhodium oxide (Rh_2O_3) is prepared by Ball Milling process. A ball mill works on the principle of impact size reduction is done by impact as the ball drop from near the top of the shell. High energy ball milling process is a powder metallurgy processing technique involves grinding materials into extremely fine powder. The impact energy of the milling balls in the normal direction attains a value of up to 40 times higher than that due to gravitational acceleration. However the bulk materials are altered into nano sized materials due to high-energy collision from the balls and bowls. The High energy ball milling machine is operated at 450 rpm to convert the Rhodium oxide into Nano Rhodium oxide. The particle size is characterized using scanning electron microscope (SEM). The obtained particle size range is from 100 nm.

Figure 1. Ball Milling Machine

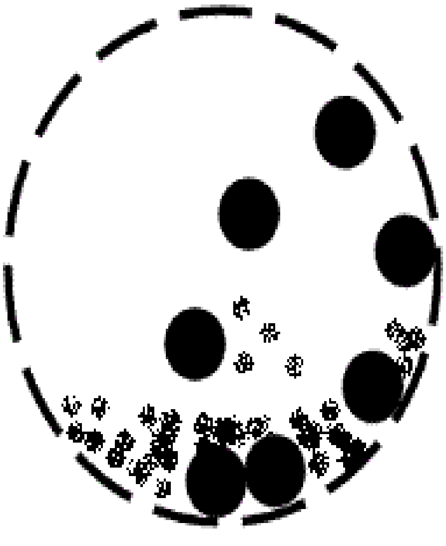

Figure 2. Ball Milling Process

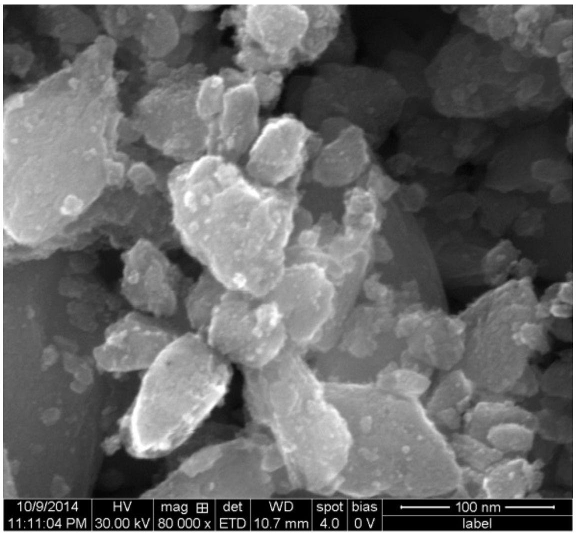

Figure 3. SEM Image of Rhodium Oxide

III. NANO FLUID PREPARATION

The prepared nano particles were added to the biodiesel and dispersion stability were studied. The Nano particles were dispersed in the fuel by using Magnetic stirrer. Nano particles are generally having higher surface area and hence surface energy will be high and it will tend to agglomerate to form a micro molecule and starts to sediment. In order to make nano particle to be stable in a base fluid, it should be evolved to surface modification. Cetyl Trimethyl Ammonium Bromide (CTAB) is a cationic surfactant and it forms an envelope on the surface of the particle and makes the surface as a negative charge. Hence the particle sedimentation was controlled. In order to disperse the nano particle to base Magnetic stirrer procedure was followed. A known quantity of additive and of CTAB were weighed and poured in the biodiesel and magnetic stirrer for 2 hour. Then it forms a stable nano-fluid.

Figure 4. Nano fluid preparation

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IV. MECHANISM OF RHODIUM OXIDE

A rhodium oxide (Rh2O3) has a hexagonal form of corundum structure it transforms into an orthorhombic structure when heated above 750^{0}C. The former is an active site for CO oxidation because those having valence higher than +3 is highly unstable. CO oxidation mechanism depends on two kinds of oxygen. The mobility of active oxygen is clearly affects by thermal treatment. Higher the temperature becomes the active oxygen is more mobile. And the oxidation becomes easier. The lattice oxygen on the Rhodium oxide is active more than the active oxygen and forms an intermediate.

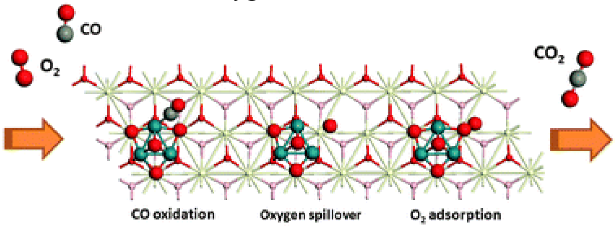

Figure 5. Catalyst Mechanism

Nano particles (Rh_2O_3) are highly energetic materials and burns during the combustion process. All nano particles are coated with CTAB. The nano particles form a layer and hence droplets shape is swollened. At high temperature sudden explosion take place and the fuel are available in the core area of droplet (2) as show in Figure 6.

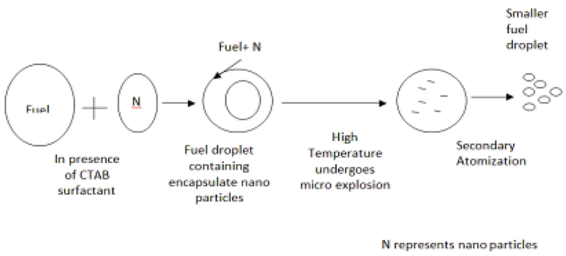

Figure 6. Micro explosion of nano particles

V. EXPERIMENTAL PROCEDURE

The procedure involves measuring the performance and emission characteristics of biodiesel with additive and surfactant. Engine details are given in Table 2. A single cylinder, direct injection (DI) diesel engine was connected to an electrical dynamometer. The power output is measured by electrical dynamometer. Time taken for fuel consumption was measured with the help of burette and stop watch. Exhaust gas temperature is measured by thermocouple. The results are plotted against brake mean effective pressure (BMEP).The experimental setup are shown in the figure 7. BMEP 1 bar 2 bar and 3 bar are loads of the test engine.

Table 2 Engine specification

Type	Single cylinder, four store, air cooled direct injection diesel engine
Capacity	661 cc
Bore × stroke	87.5 mm × 110 mm
Compression Ratio	12:1 to 18:1
Speed	1500 RPM
Rated power	3.5 kw
Injection Timing	25 ^{0} btdc
Injection Pressure	220 bar


Figure 7. Expermental setup

VI. RESULT AND ENGINE PERFORMANCE DISCUSSION

A. Brake specific energy consumption

The variation of brake specific energy consumption (BSEC) for Pongamia biodiesel, biodiesel with Nano-fuel additives and diesel fuel with brake mean effective pressure. Biodiesel having lesser calorific value compared to diesel fuel, hence to maintain the same power output excess amount of fuel was consumed during neat biodiesel operation. This leads to higher fuel consumption of biodiesel compared to diesel. To enhance the engine performance Nano-fuel additives (Rhodium Oxide) was added with the biodiesel. The addition of Rhodium oxide additive resulted in 3% reduction in BSEC at full load due to catalytic chemical oxidation of fuel which in turn improves the combustion of fuel. The variations of BSEC are shown in the figure 8.

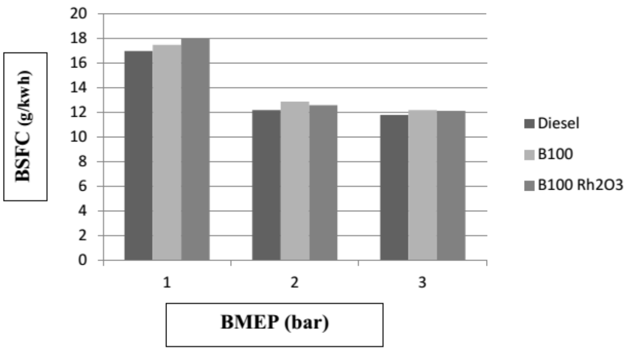

Figure 8. BMEP vs. BSFC

B. Brake Thermal Efficiency

The differences of brake thermal efficiency for pongamia biodiesel, biodiesel with additive and diesel fuel with brake mean effective pressure is shown in Figure 6. Brake thermal efficiency is lowest for neat biodiesel at all loading conditions, because of lower volatility, lower heating value, higher viscosity, and density compare to diesel fuel. Nearly 15-20% of fuel is typically converted in to mechanical energy. The remaining energy is radiated to the atmosphere as waste heat. In order to utilise the chemical energy available in the fuel, Nano-fuel additives (Rhodium oxide) were added and its

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effects are investigated in this study. For biodiesel there is a reduction in thermal efficiency compare to diesel, this is due to lower calorific value and ineffective utilisation of heat energy due to higher molecular weight of methyl ester, which combust entirely on diffusion scorching, late in the expansion stroke. It results in power reduction. The addition of Rhodium oxide leads to marginal improvement in thermal efficiency compare to neat biodiesel operation at full load. Because metal/metal oxide additive reduces the evaporation time of the fuel and hence it reduces the physical delay. Rhodium Oxide possessing higher activity and can react with water vapour formed during combustion at high temperature and it generates hydrogen and improves the fuel combustion.

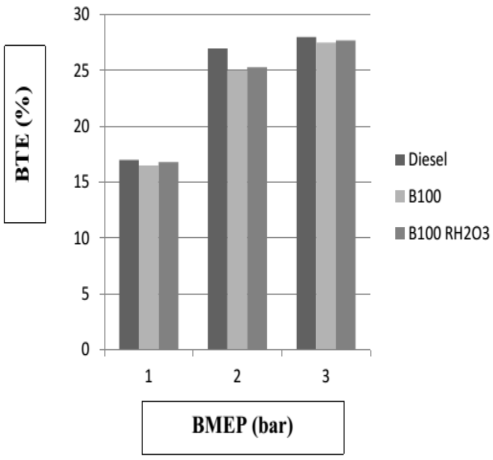

Figure 9. BMEP vs. BTE

EMISSION CHARACTERISTICS

C. Hydrocarbon

The differences of HC emission for pongamia biodiesel, biodiesel with additive and diesel fuel with brake mean effective pressure are shown in figure10. Hydrocarbon emission was reduced in case of neat biodiesel compare to diesel operation due to fuel bound oxygen, which improves the combustion and reduces the fuel rich zone.

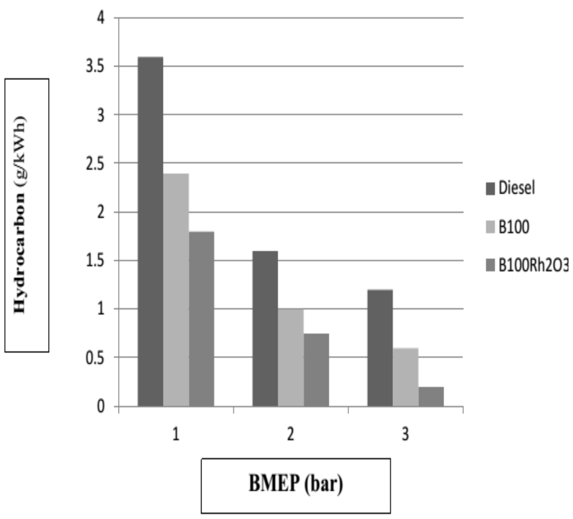

Figure 10. BMEP vs. HC

The main reasons for HC emission are fuel rich zone, flame quenching, misfiring and desorption of lubrication oil. By adding additives there is a further reduction in HC emission was noticed. The Rhodium oxide Nano fuel additive act as an oxygen buffer and donates its lattice oxygen and avoids fuel rich zone which results in 45 % reduction in HC emission compare to neat biodiesel operation. Hence mixing will be better and fuel burns completely.

D. Oxides of nitrogen

The variations of NO_x emission for Pongamia biodiesel, biodiesel with Nano-fuel additive and diesel fuel with brake mean effective pressure shown in the figure. More significant factor that cause NO_x formation are higher combustion temperature and other factors like injection period, combustion quality and injection timing. By increasing the proportion of biodiesel, NO_x increases because the presence of fuel bound oxygen promotes better combustion, resulting in higher in cylinder temperature. Due to higher bulk modulus, injection will be advanced by nearly 2° for pure biodiesel is also a reason for NO_x emission. The addition of Nano-fuel additives resulted in an effective reduction in NOx emission. Rhodium oxide showing better reduction at all loads. Rhodium oxide is an active single metal oxide catalyst for NO_x decomposition. Therefore it reduces the NO_x. It was observed that operation, reduction is about 37% in case of Rhodium oxide Nano-fuel additive.

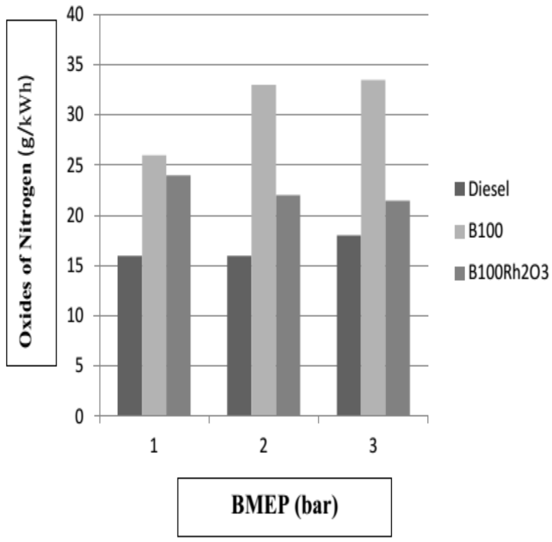

Figure 11. BMEP vs. NO_x

E. Carbon monoxide

Figure 12 show the variation of carbon monoxide (CO) for Pongamia biodiesel, biodiesel with nano fuel additive and diesel fuel with brake mean effective pressure. The main reason for higher CO emission is due to fuel rich combustion and it is an intermediate product formed during combustion. It is emitted in the exhaust stream when its progression to CO_2 is not completed due to lack of oxygen or when engine is running in too rich condition. There is a reduction in CO

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emission for biodiesel compare to diesel; this is due to 10 to11% oxygen possessed by biodiesel. By adding additives in Nano range, there is an effective reduction in CO emission. Hence lower CO emission was observed. By adding Rhodium oxide, there is a 45% reduction in CO emission at load .This is because Rhodium oxide acts as an oxygen buffer and donates surface lattice oxygen.

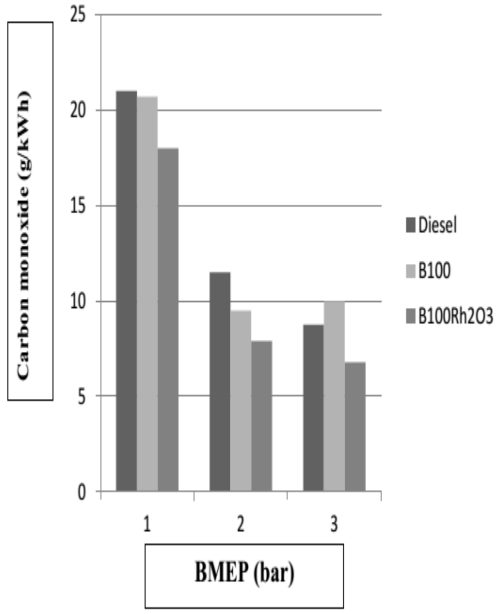

Figure 12. BMEP vs. CO

VII. Conclusion

In the present investigation of Pongamia Biodiesel engine performance and emission characteristics are studied and based on the experiment the following conclusion are,

- Biodiesel having lower efficiency and higher energy consumption, because of its lower heating value. The addition of nano additives there is a significant improvement in efficiency compare to biodiesel operation without additives.
- A marginal enhancement in brake thermal efficiency was observed with the use of Nano rhodium oxide.
- The reduction in HC emission by using biodiesel, because of its fuel bond O_2, Rhodium oxide showing 45% reduction in HC compare with biodiesel.
- Nano fuel additive reduce CO emission is up to 45% compare with biodiesel, because rhodium oxide act as an oxygen buffer and donates surface lattice oxygen.
- NO_x Emission increases by using biodiesel compare to diesel. By comparing nano additive rhodium oxide betters NO reduction. Rhodium oxide nano fluid was observed 37 % reduction of NO_X.

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