Effects of Alumina Nano Metal Oxide Blended Palm Stearin Methyl Ester Bio-Diesel on Direct Injection Diesel Engine Performance and Emissions

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Abstract: The Present Investigation was carried out to study the effect of Alumina Metal Oxide (Al_2O_3) Nano Particles as additive for Palm Stearin Methyl Ester Biodiesel (B 100) and their blends as an alternate fuel in four stroke single cylinder water cooled, direct injection diesel engine. Alumina Nano Particles has high calorific value and relatively high thermal conductivity (30^{-1} W m K^{-1}) compare to diesel, which helps to promote more combustion in engines due to their higher thermal efficiency. In the experimentation Al_2O_3 were doped in various proportions with the Palm Stearin Methyl Ester Biodiesel (B-100) using an ultrasonicator and a homogenizer with cetyl trimethyl ammonium bromide (CTAB) as the cationic surfactant. The test were performed on a Kirsloskar DI diesel engine at constant speed of 1500 rpm using different Nano Biodiesel Fuel blends (psme+50 ppm, psme+150 ppm, and psme+200 ppm) and results were compared with those of neat conventional diesel and Palm Stearin Methyl Ester Bio diesel. It was observed that for Nano Biodiesel Fuel blend (psme+50ppm) there is an significant reduction in carbon monoxide (CO) emissions and Nox emissions compared to diesel and the brake thermal efficiency for (psme+50ppm) was almost same as diesel.

Keywords: Nano particles, Biodiesel, Alumina Oxide, Diesel Engine, Performance, Emissions.

I. INTRODUCTION

In this 21st century as demand is more, supply is less. One of the key to country's growth is transportation. Transportation plays a major role in any sector. Because of the transportation world is moving further. Due to the modernization numbers of vehicles are increasing. The main key energy of vehicle is fuel (petroleum product). Fossil fuels (crude oil) are not evenly distributed in the world, there is an imbalance of fossil fuels which effects the country's economy by importing. Due to extensive use of vehicles, pollution levels are increasing significantly. The effects of these pollutants are directly on the living things and environment. Biodiesel is a promising alternative for our Diesel needs. In the view many scientists searched for an alternate to diesel fuel to preserve global environment and to with stand economical crisis. So, vegetable oils from plants both edible, crude non-edible and Methyl esters

(Bio-diesel) are used as alternative source for diesel oil. Palm stearin methyl ester has the advantages of higher cetane number, oxygen content and it is clean and also renewable. While Biodiesel having certain disadvantages such has higher viscosity, higher pour point, lower calorific value, higher emissions.
In order to resist the problems related with biodiesel, a fuel additive were being used. Generally a Nano additive improves the combustion efficiency due to their high energy content and reduces exhaust emissions. Metallic based fuel additive compounds, such has alumina, manganese, iron, copper, barium, calcium and platinum etc., have been used as fuel additive for hydrocarbon fuel.
Ali M.A. Attia and Mohamed S. Shehata [1] conducted experiment on Effects of Alumina Nano Particles Additives into Jojoba Methyl Ester-Diesel Mixture on Diesel Engine Performance. For this study alumina nano-particles are taken and added to a mixture of jojoba methyl ester (biodiesel) and conventional diesel fuel (20% biodiesel and 80% diesel fuel) with different doses from 10 up to 50 mg/l. They observed that at 30 mg/l the overall BSFC is reduced by about 6%, engine thermal efficiency is increased up to 7%, and all engine emissions have been reduced (NOx about 70%, CO about 75 %, smoke opacity about 5%, and UHC about 55 %) compared with the corresponding values obtained when only a blended fuel of 20% biodiesel is used. C. Syed Aalam , C.G. Saravanan [2] conducted experiment on Effects of nano metal oxide blended Mahua biodiesel on CRDI diesel engine. They conducted experiment on CRDI diesel engine at a constant speed of 1500rpm using different ANP-blended biodiesel fuel (MME20 + ANP50 and MME20 + ANP100).They observed substantial enhancement in the brake thermal efficiency and a marginal reduction in the harmful pollutants (such as CO, HC and smoke) for the nanoparticles blended biodiesel MME20 + ANP50. They also observed that ANP reduced HC and CO emissions up to 26.04% and 48% compared with a biodiesel blend (MME20). AmbarishDatta, Bijan Kumar Mandal [3] conducted experiment on the performance, combustion and emission parameters of a compression ignition engine fuelled with diesel, palm stearin biodiesel and alcohol blends. They have consider a blend of 15 % Bio diesel (palm stearin methyl ester) and 85 % diesel and another blend of 15 % biodiesel, 70 % diesel and 15 % alcohol (both ethanol methanol separately) as fuels. Their experimental result showed that the harmful emissions in terms of CO2, NOx, PM are reduced by an amount of 1.36%, 25.10%, 56.88% respectively, for ethanol blending. But, the thermal efficiency increases with ethanol and methanol addition to diesel–biodiesel blend by 1.73 and 2.47 %, respectively.

Sajith V and Mohamed PM [4] carried out experiment on Development of Stable Cerium Zirconium Mixed Oxide Nanoparticle Additive for Emission Reduction in Biodiesel Blends .In this experiment jatropha oil was taken as bio diesel. Synthesized cerium zirconium mixed oxide nanoparticles were in the size range of 20 - 30 nm. To B5, B10 and B15 7.5 ppm, 10 ppm and 15 ppm of nano particles were added and blended and used as a fuel. The experimental results indicated that there was an 15% average reduction of NO emissions was observed for B5 and B10 blends with 15 ppm of catalytic nanoparticle concentration. A maximum reduction of 25% was observed in HC emission for B15 blend with 15 ppm catalytic nanoparticle concentration.

D. Ganesh and G. Gowrishankar [5] conducted investigation on the Effect of Nano Fuel Additives [Magnalium (Al-Mg) and cobalt oxide (Co3O4)] on the Performance and Emission Characteristics of Jatropha Biodiesel (B100) in a Single Cylinder, Air Cooled, Direct Injection

Diesel Engine. The nano particle size was in the range of 38 – 70 nm. The nano particles (100 mg/l) were dispersed in the fuel by an ultrasonicator with the assistance of optimized surfactant (CTAB) concentration. They observed that 1% improvement in thermal efficiency for magnalium additive compare to B100 without additive. NOx emission increased for biodiesel (B100) compare to diesel. By comparing two additives cobalt oxide has better NO reduction.

S.Manibharathi, B.Annadurai, R.Chandraprakash [6] carried out Experimental Investigation of CI Engine Performance by Nano Additive in Biofuel. For this experiment rhodium oxide (Rh2O3) was considered as nano additive and pongamia oil as bio diesel. Rhodium oxide size was in the range of 100nm. Nano fuel additive reduces CO emission up to 45% compare with biodiesel, 37 % reduction of NOX compared to bio diesel. K.Fangsuwannarak and K. Triratanasirichai [7] conducted Investigation on Improvements of Palm Biodiesel Properties by Using Nano-TiO2 Additive, Exhaust emission and Engine Performance .B2, B10, B20, B30, B40, B50 , and B100 are taken as fuel in this nano-TiO2 were added. It was observed that addition of 0.1% nano-TiO2 level in the fuel improved the engine performances. For B100_0.1% sample as compared with standard B20 fuel, a maximum increase of around 1.56% in the average brake power was obtained at low speed range of 1600-3000 rpm. On the other hand, B100_0.1% sample provided a maximum decrease of around 2.43% in the average brake power at high speed range above 4000 rpm. The most effectiveness of an average CO emission reduction of around 29% is to dose 0.1% nano-TiO2 additive in B20 fuel blend. S.Ch. Rao, M.SrinivasaRao [8] conducted experiment on Performance Analysis of DI Diesel Engine Fuelled with Diesel along with Nano Additives. Cerium oxide and zinc oxide were considered as the nano additives. The experiment was conducted for 40ppm , 80ppm, 250ppm and 500ppm nano additives. The result showed that brake specific fuel consumption of zinc oxide 250ppm nanoparticle is nearly same as cerium oxide 40ppm and also zinc oxide 500ppm blend is nearly same as cerium oxide 80ppm at higher loads. The smoke was found lower when using the 40ppm cerium oxide nanoparticles compared to the neat diesel and other nano additives. Marginal improvement was observed in brake thermal efficiency by adding nanoparticles at full load.

The equation between viscosity and Higher Heating Values for vegetable oils is

$$HHV=0.0317v+38.053 \quad (1)$$

For Biodiesel $HHV=0.4625v+39.450$

(2)

The equation between density and higher heating value for biodiesel is:

$$HHV=-0.0259\rho+63.776 \quad (3)$$

The equation between flash point and higher heating value for biodiesel is:

$$HHV=0.012FP+32.12$$

(4)

The measured Cetane number and physical properties of the biofuels were analyzed to obtain regression equation and to rank the physical properties based on R2 values. The following physical properties are ranked in descending order based on precision (R2) of predicting Cetane numbers: boiling point> viscosity> heating value> carbon number> melting point> density [9]. The present investigation to study the effects of alumina nanoparticles added to a mixture of palm stearin methyl ester biodiesel (B 100) by volume.

Table 1. Properties Biodiesel-Nano Particles and Diesel

Description	viscosity @ 40°C (cSt)	Density @15°C (kg/m³)	Calorific value (kJ/kg)	Flash point(°C)	Cetane number
Diesel	3	815	42,000	56	47
PSME	4.52	871.96	38,000	192	60
PSME+50ppm	4.61	871.94	41,128	130	51
PSME+150ppm	4.60	872.81	46,600	95	53
PSME+200ppm	4.60	872.82	49,536	69	55

II. BIO-DIESEL PRODUCTION

Palm oil is processed into palm olein and palm stearin. Palm stearin is the solid fraction of palm oil that is produced by partial crystallization at controlled temperature. It is more variable in composition than palm olein, the liquid fraction of palm oil, especially in terms of its solid fat content, and therefore has more variable physical characteristics. Palm oil with an estimated global (annual) production of 25-27 million tons is the second most produced oil in the world. The leading producers of palm are Malaysia (13 million tons) and Indonesia (10million tons), and together they have provided about 80% to 90% of the world's palm oil. Palm stearin methyl ester is used as alternate fuel for diesel engine which is refined from palm oil Figure 6.

III. NANO BIODIESEL PREPARATION

The Nano particles bio diesel fuel is prepared by mixing the aluminum oxide nano particles in the palm stearin methyl ester with the aid of an ultrasonicator Figure 1. The ultrasonicator technique is the best suited method to disperse the nano particles in base fuel (palm stearin methyl ester), as it facilitates possible agglomerate nanoparticles back to nanometer range Figure 5. 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. CetylTrimethyl 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 fluid ultrasonication procedure was followed. A known quantity of (say 100 mg) additive and of CTAB (100 mg) were weighed and poured in the biodiesel and ultrasonicated for 1 hour. Then it forms a stable nano-fluid Figure 2.

IV. EXPERIMENTAL SET UP AND TEST PROCEDURE

Details of engine specifications are given in Table 2. The tests were conducted on Kirloskar TV 1, four stroke, single cylinder direct injection, water cooled diesel engine at the rated output 5.2 kW at 1500 rpm from Figure 3. Initial tests were conducted with diesel to prove the base line data and then it was fuelled with PSME, PSME+50ppm, PSME+150ppm and PSME+200ppm. Eddy current dynamometer was used for loading the engine. The MARS five gas analyser was used to measure CO_2, CO, HC, and NOx exhaust Emissions. The experimental is shown in

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Table 2. Specifications of Engine

Make and Model	Kilsoskar,TV1
Number of cylinders	One
Cylinder bore	87.5 mm
Stroke	110 mm
Compression Ratio	17.5
Swept volume	661 cc
Rated Output	5.2 kW
Cooling Type	Water
Rated Speed	1500 rpm
Dynamometer Type	Eddy Current
Nozzle opening Pressure	180 bar
Fuel Injection Timing	23° CA b TDC Diesel
Fuel	

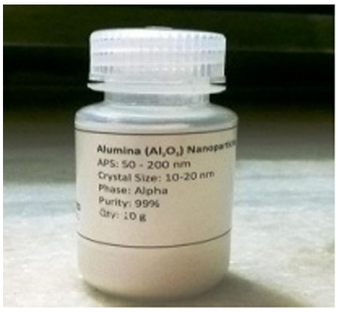

Figure 1 Alumina NanoParticle

Figure 2 Ultrasonicator

Figure 3 Experimental engine

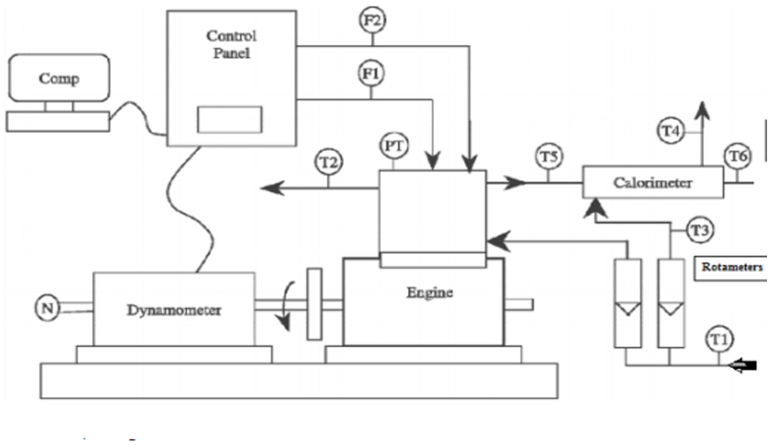

Figure 4 Computerized single cylinder-stroke DI Diesel Engine with Eddy Current Dynamometer

1.Water inlet Tmperature (T1°C)

2. Water inlet from the calorimeter (T3°C)

3.Water outlet Temperature (T2)

4. Water outlet from the calorimeter (T4°C)

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5. Calorimeter Exhaust gas inlet Temperature (T5°C) 6.Calorimeter Exhaust gas outlet calorimeter (T6°C)

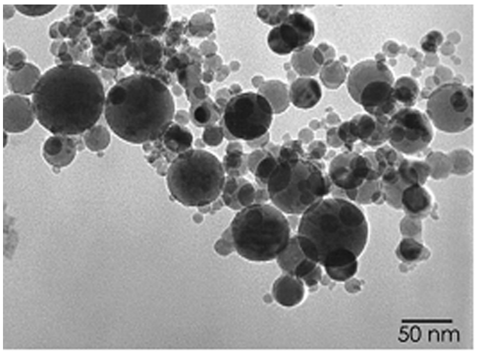

Figure 5 AL_2O_3 SEM

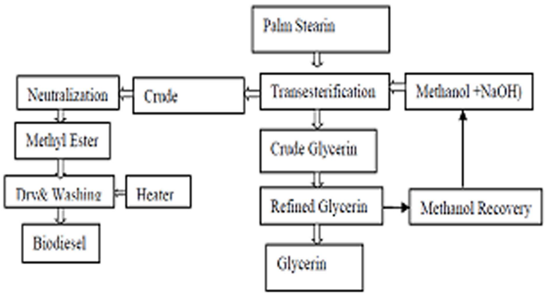

Figure 6 Biodiesel Production Plant diagram

V. RESULTS AND DISCUSSION

Brake thermal Efficiency

Brake thermal efficiency is defined as how well an engine converts the heat from a fuel to mechanical energy. From the Figure 7. Brake thermal efficiency (BTE) increases with the load for all the fuels (PSME, PSME+50ppm, PSME150ppm, and PSME200ppm). The BTE of PSME and PSME+50ppm is better than that of remaining blends and conventional diesel due to the higher cetane value of fuel. For PSME+150ppm and PSME200ppm there is a reduction in BTE compared to diesel, due to higher oxygen content in the alumina nanoparticles.

Brake Specific Fuel Consumption

Figure 8 with the increase in load, brake specific fuel consumption decreases. It is related with brake thermal efficiency. At higher load conditions the brake thermal efficiency is increased and brake specific fuel consumption decreased. It was found that BSFC is minimum for pure diesel, when compared to PSME, PSME+50ppm, PSME+150ppm, PSME+200ppm. To enhance the engine performance AL2O3 was added to the biodiesel. The addition of additive a marginal increment in BSFC due their higher viscosity.

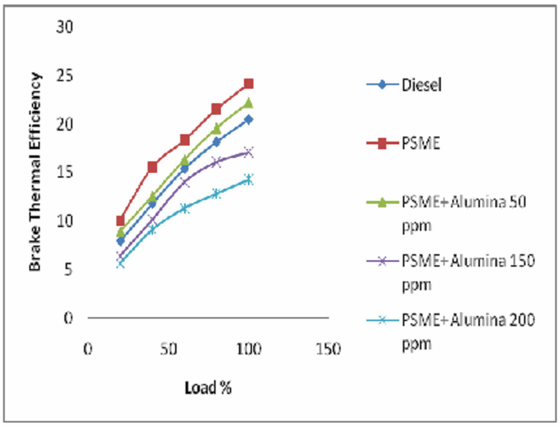

Figure 7 Variation of BTE Vs Load

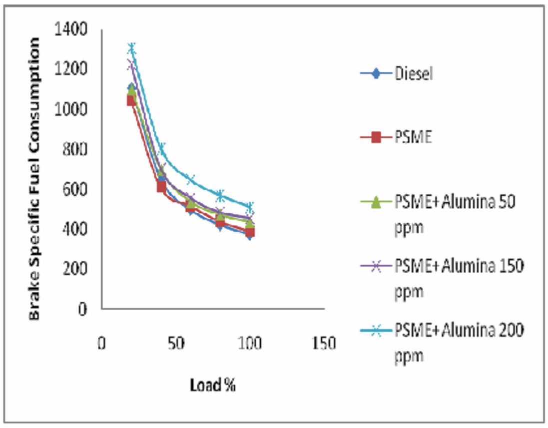

Figure 8 Variation of BSFC Vs Load

EMISSION CHARACTERISTICS

Carbondioxide (CO_2)

Figure 9 shows the variation of CO_2 emission for PSME, PSME+50ppm, PSME150ppm, PSME+200ppm, and conventional diesel with 20%, 40%, 60%, 80%, and 100% load. It was observed that as the load increases the CO_2 emissions steadily increases for all conditions. Carbondioxide emissions were reduced when compared to base line fuel except PSME because of their brake thermal efficiency energy released is less.

Nitrogen Oxide (NOx)

It was observed that from the Figure 10 the Oxides of Nitrogen (NO_x) levels are higher with biodiesel compared to diesel operation. NO_x emissions increase with biodiesel operation due to the reactive nature of biodiesel molecule at higher temperature and oxygen present in its structure. By adding aluminium oxide, there is reduction in NOX emission. This is because aluminium oxide acts as an oxygen buffer and donates surface lattice oxygen. It was observed that bio diesel with 50ppm aluminium oxide has 9.70% less NOX formation than diesel.

Unburned Hydrocarbon (UBH)

The variation of unburned hydrocarbon emission with 20%, 40%, 60%, 80%, and 100% load shown in Figure 11. Hydrocarbon emissions are formed as a result of incomplete combustion of fuel and quenching of flame near the combustion chamber walls. The UBH emission for PSME is higher than that of PSME150ppm and PSME+200ppm blended fuel due to their lower thermal efficiency resulting in incomplete combustion. However, the UBH emission is same for PSME+50ppm blend fuel than biodiesel (B 100). This could be due to catalytic activity and improved combustion characteristics of the AL2O3 nanoparticles blended fuel.

Carbonmonoxide (CO)

Figure 12 shows the variation in the CO emission for the tested PSME blended fuels. CO is an intermediate combustion product and is predominantly formed due to the lack of oxygen and incomplete combustion .If combustion is complete CO will be converted to CO_2. CO are found to be considerably reduced on the addition of the alumina oxide additive. This is due to the improved fuel air mixing in the combustion chamber. It was observed that bio diesel with 50ppm aluminium oxide has 39.21% (on an average) less CO formation than diesel.

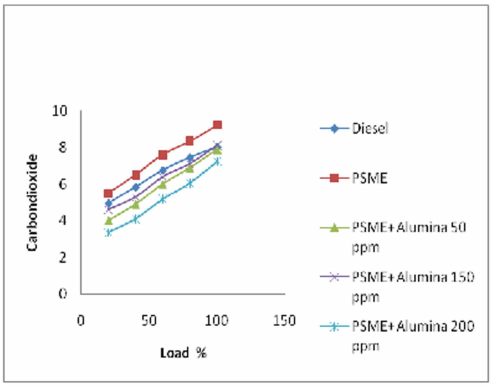

Figure 9 Variation of CO_2 Vs Load

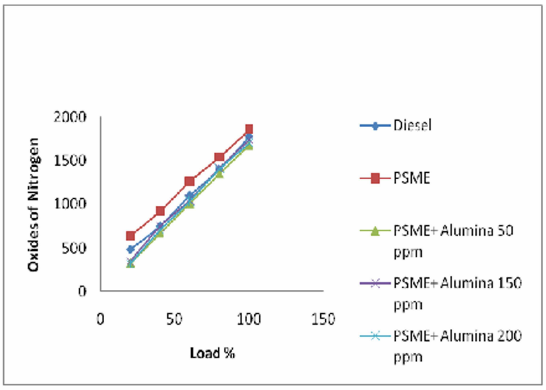

Figure 10 Variation of NOx Vs Load

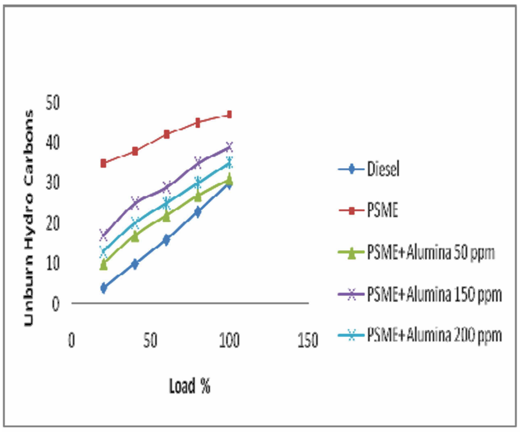

Figure 11 Variation of UBH Vs Load

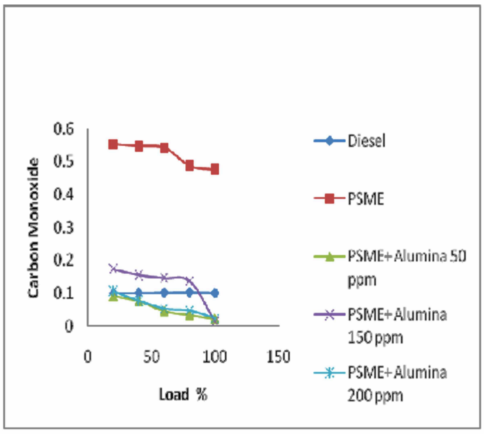

Figure 12 Variation of CO Vs Load

VI. Conclusion

The experiment was conducted to investigate the effect of Alumina Metal Oxide (AL2O3) Nano particle as additive for Palm Stearin Methyl Ester on performance and emission characteristics of CI engine, based on the experiments the following conclusions are drawn:

- The break thermal efficiency was almost same for diesel and palm stearin methyl ester blended with alumina (50ppm).
- By using palm stearin methyl ester blended with alumina (50ppm) the carbon monoxide (co) emissions were decreased by 39.21% compared to diesel.
- The NOX emissions were decreased by 9.70% for 50ppm alumina nano particle blended with palm stearin methyl ester compared to diesel.
- Palm stearin methyl ester (B 100) has higher NOX emissions.
- On the whole it is concluded that 50ppm alumina can be used as additive with biodiesel which showed reduction in emissions as well as compatible performance characteristics with diesel.

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