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Experimental investigations on the performance and emission characteristics of diesel engine fueled with pongamia methyl ester biodiesel with varying concentration of zinc oxide nanoparticles

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Abstract - **The effect of zinc oxide nanoparticles as a fuel additive was experimentally investigated with pongamia pinnata biodiesel in a four-stroke, single cylinder, direct injection diesel engine. The study aimed at the reduction of harmful emissions of diesel engines including oxides of nitrogen (NO_x) and smoke and CO, CO_2 and HC and to increase the performance characteristic of B20 blend of pongamia pinnata bio diesel (20% of volume of bio diesel 80% volume of diesel). The nanoparticles of zinc oxide are dispersed in the tested fuels at a dosage of B20+50 ppm, B20+100 ppm, B20+150 ppm with the aid of an ultrasonic homogenizer. Tests were conducted at a constant engine speed of 1500 rpm and varying loads (from 0 to 12 kg) with B20 bio diesel of pongamia pinnata biodiesel and other B20 Nano fuel blends. The engine combustion, performance, and emission characteristics for the fuel blends with nanoparticles were compared with B20 as a base fuel. The test result showed that Brake thermal efficiency of B20+150 ppm of zinc oxide nano particle shows the highest efficiency compared with the B20 other blends at 75% of load and there is an increase in 2.62% of BTE when compared to B20 biodiesel, the of BSFC of B20+150 ppm of zinc oxide decrease by 8.52% compared B20 bio diesel, the CO_2 emission of B20+150 ppm of zinc oxide decreases by 5.20% compared to B20 neat blend, At full load CO emission of B20+150 ppm of zinc oxide decreases by 15% compared to B20 neat blend. In the overall analysis of experiment, the blend of B20+150 ppm of ZnO is found more favorable compared with other blends of the experiment.**

Index Terms - **BIO DIESEL, NANO PARTICLE, PONGAMIA PINNATA, ZINC OXIDE.**

I.INTRODUCTION

Diesel engine plays an essential role in power generation, transportation and industrial activities. The advantage of the diesel engine over the gasoline spark ignition engine are its durability, reduced fuel efficiency. Due to higher efficiency, diesel engines are of more interest in heavy and light duty vehicles. The diesel engine produces dangerous emissions such as oxides of nitrogen, carbon monoxide, carbon dioxide (CO_2), hydrocarbons and smoke out of these pollutants carbon monoxide is prime pollutant followed by hydrocarbons. Increased fuel price and consumption of the stock fossil fuels are the two major concerns currently experienced by globally. As fossil fuels are limited sources of energy, this increasing demand for renewable energy has led to a search for alternative sources of energy that would be economically efficient, socially accepted, and environmentally sound. Biofuels are the best available sources, to fulfill the energy requirement of the world. In this ethanol is one of the alternate renewable sources. It is derived from biomass. It is one of the source of clean and green energy for world's sustainable development environment. Furthermore, it reduces the hazardous emissions of the engine. However, due lower heating value it slightly increases the fuel consumption. It was found that the addition of pongamia biodiesel of B20 blend has properties similar to diesel fuel, and it can be used in diesel without significant alteration in the diesel engine [1]. Innovative techniques are in progress to enhance the performance and reduce the harmful emission of the diesel engine, the researchers are tried out to enhance the performance of diesel engine by engine modification, exhaust gas treatment, fuel modification etc. [2, 3, 4]. Fuel modification technique includes blending of diesel and biodiesel in various proportions, blending of oxygenated additives with diesel and biodiesel, blending of nano additives with diesel and biodiesel. It is found that addition of nano particles in bio diesel further improve the performance of C.I engine [5]. They act as effective catalyst when added to the diesel and bio diesel blends, which provide oxygen for complete combustion of fuel. Zinc oxide(ZnO) nano particles are also used in this work. Nano particles, improves the oxidation rates, due to this, complete combustion takes place. Nano particles hold unusual properties, resulting from their high surface area [6].

II.LITERATURE SURVEY

Rolvin D'Silva [7] has found that viscosity and a density of the fuel taken are found to increase with nano additives. The brake thermal efficiency (BTE) was improved with the CuO nano additives to a biodiesel. At the highest load B20+10 ppm CuO gives the highest BTE when compared with B20 blend. Among all the samples taken, it is noted that B20+50 ppm CuO has the lower BSFC compared to other blends. CO emissions can be decreased by increasing the CuO nano additives concentration in B20 blend. Smoke emission is less in B20+50 ppm CuO as compared to other blends. Smoke can be decreased with an increase in of CuO nano additives in B20 blend. It is found that performance and emission characteristics is improved with addition of CuO nanoparticle in B20 blend.

Jeryrajkumar, [8] has found performance and emission characteristics of single cylinder diesel engine using calophyllum inophyllum biodiesel and modified biodiesel (B100 CO_3O_4 and B100 TiO_2) were examined. In HC emission cobalt oxide showing 80% decrease at full load. Titanium dioxide showed that 70% decrease in 75% load. In NOx emission cobalt oxide and titanium dioxide resulted that improves gradually at all loads as compared with pure biodiesel. In CO emission the cobalt oxide blended biodiesel resulted 30% decrease in CO emission at full load. Titanium dioxide blended biodiesel resulted 25 % improvement in CO emission at the full load state. According to this performance and emission analysis, the brake thermal efficiency was improved with Nano additives.

Muthusamy Sivakumar[a] [9] conducted the experiment with the test fuels are specified as B25 (75% diesel and 25% PME) and B25 A50 (75% diesel and 25% PME and 50 ppm Aluminum oxide nanoparticles) and B25A100 (75% diesel and 25% PME and 100 ppm Aluminum oxide nanoparticles) respectively. The results indicate that the brake thermal efficiency for aluminum oxide nanoparticles blended pongamia methyl ester increases marginally while a brake specific fuel consumption (BSFC) reduces when compared to other blends. The carbon monoxide (CO), unburnt hydrocarbon (HC) and a smoke emission slightly decrease as compared to a mineral diesel. The blending of aluminum oxide nanoparticles in biodiesel blends produces most hopeful results in engine performance and also reduces the hazardous emission from engines.

III.MATERIALS AND METHODS

1. Preparation of biodiesel

One of the foremost common methods to reduce oil viscosity within the biodiesel industry is named transesterification which takes place between an oil and an alcohol within the presence of a catalyst. Transesterification is basically a chronological reaction. Triglycerides are first reduced to diglycerides. The diglycerides are subsequently reduced to monoglycerides. The monoglycerides are finally reduced to carboxylic acid esters. Equipment's required for transesterification reaction are magnetic stirrer, thermometer, and beaker. Raw materials are pongamia oil, methanol, and potassium hydroxide. pongamia oil was measured to a volume of 1000 ml and filled into the primary beaker. Then, it had been stirred at 1000 rpm and then the oil was warmed up to 60 °C. In addition, 5g of potassium hydroxide was dissolved in 250ml of methanol followed by forceful stirring. This alcohol mixture was added to the pongamia oil and stirred vigorously at 1000 rpm for 1 hour at 60 °C. Crude glycerin, the heavier liquid, was separated at rock bottom and methyl ester on the highest. After completion, water at 80 °C is added to double volume of methyl ester, then stirred for 15 minutes. The glycerin was allowed to settle again. The process was continued until the ester layer becomes clear.

2. Preparation of fuel blend

For the blending of zinc oxide nanoparticles in a biodiesel, taken a sample of B20 pongamia biodiesel say a liter and then 0.05g of zinc oxide is added in the biodiesel to make the dosing level of 50 ppm. The dosing level of 50 ppm is 0.05 g, respectively. After the addition of zinc oxide nanoparticles, and then it is poured into a mechanical homogenizer apparatus where it is agitated for about 30 minutes in an ultrasonic vibrator. The ultrasonicator technique is the best suited method to disperse the both nanoparticles in the base fuel, as it facilitates possible agglomerate nanoparticles back to a nanometer range making a uniform dispersion. The process is repeated for a 100 ppm and 150 ppm respectively.

Table 1: Variations of fuel properties with blends

Blends	Calorific value(kJ/kg)	Density @ 25 °C kg/m^3	Flash point °C
B20	41300	840	75
B20+ZnO(50PPM)	41410	839	73
B20+ZnO(100PPM)	41490	840	72
B20+ZnO(150PPM)	41560	839	70

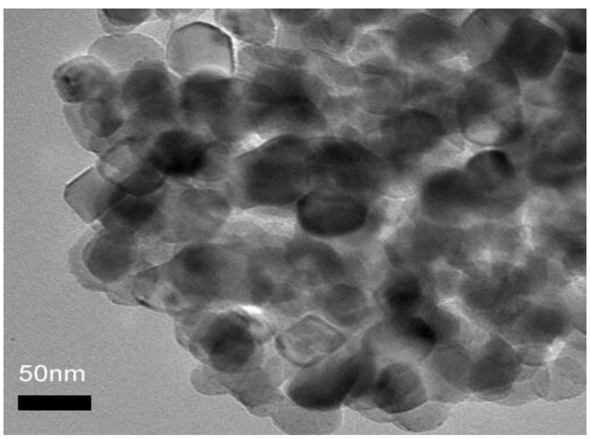
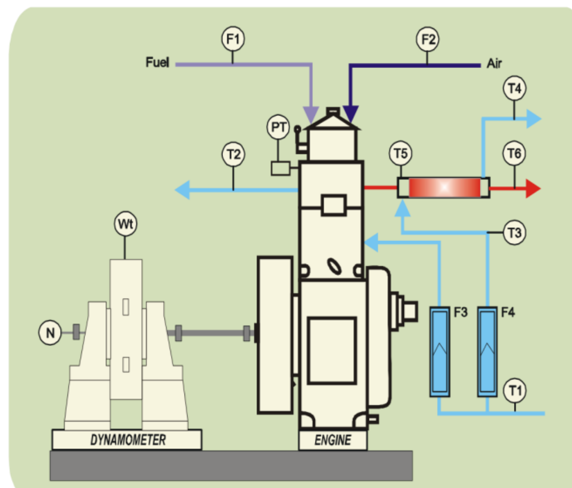


Fig 1: Transmission Electron Microscopy of Zinc oxide nanoparticle

IV.EXPERIMENTAL SETUP

A computerized single cylinder four-stroke, Direct Injection (D.I) and water-cooled, variable compression ratio diesel engine test rig of 3.5 kW rated power is used to perform the test. The experiments are carried out at varying loads at constant speeds of 1500 rpm for the various blends. The fuel samples used are, B20, B20+50 ppm ZnO, B20+100 ppm ZnO and B20+150 ppm ZnO. The compression ratio of the diesel engine can be varied from 12:1 to 18:1. It is connected directly to an eddy current dynamometer. The setup of diesel engine has independent panel box having air box, fuel tank, manometer, fuel measuring unit, transmitters for air flow and fuel flow measurements, process indicator and engine indicator. An AVL digas 444 five gas exhaust gas analyzer, is used to measure the NOx (ppm), CO (%), CO_2 (%) and HC (ppm) emissions in the exhaust. Smoke meter is used to measure the opacity of smoke in % of volume. The speed is fixed at 1500 rpm and injection pressure at 200 bar. The load is varied from 0%, 25%, 50%, 75% and 100%, in 5 steps and the tabulated readings of fuel consumption and emission readings are noted down.



Schematic arrangement

Fig 2: Schematic diagram of engine set up

Table 2: Engine specifications

Type of engine	Four stoke, water cooled, direct injection diesel engine
Make	Kirlosker
No of cylinder	1
No of strokes	4
Cylinder diameter	87.5mm
Stroke length	110mm
Fuel	Diesel
Power	3.5kw
Speed	1500rpm
CR range	12.1 to 18.1
Injection point variation	0° to 25° BTDC

V.RESULTS AND DISCUSSION

1. Brake thermal efficiency

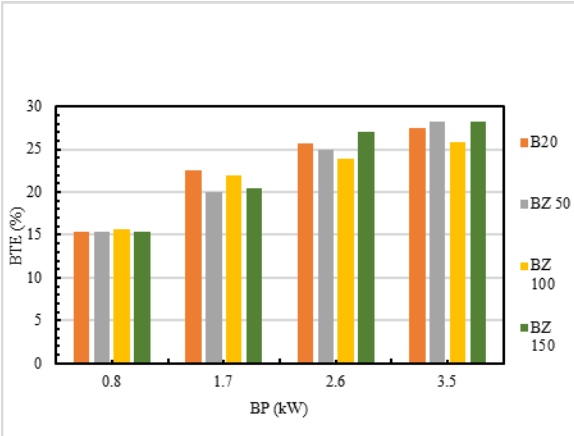


Fig 3: Variation of brake thermal efficiency with respect to brake power

It is clear from the fig 3 that brake thermal efficiency of B20+150 ppm of zinc oxide nano particle shows the highest efficiency compared with the B20 and other blends at 75% of load and there is an increase in 2.62% of BTE when compared to B20 biodiesel. The increase in brake thermal efficiency is due to the sufficient oxygen content in nano fluid. Due to high surface area per volume of nano particle it forms uniform mixture of the blend. So that the complete combustion of fuel takes place.

2.Brake specific fuel consumption

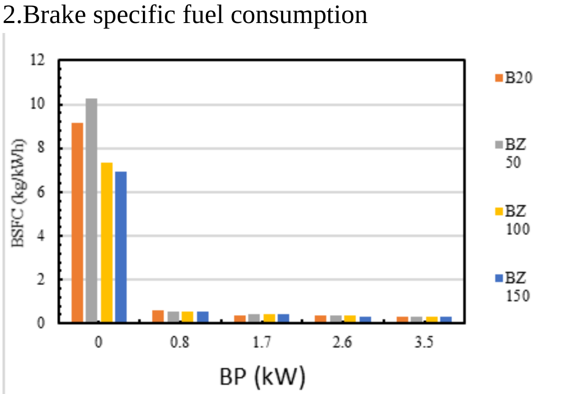


Fig 4: Variation of brake specific fuel consumption with respect to brake power

From the fig 5 it is clear that at the 75% of load BSFC of B20+150 ppm of zinc oxide nano particle shows the least BSFC compared to the other blends and there is decrease of 8.52% of BSFC compare B20 bio diesel. The decrease in BSFC is due to the addition of nano particles to biodiesel. Calorific value of the biodiesel increases with increase in the concentration of nano particles in the biodiesel. As the calorific value of biodiesel increases the BSFC value decreases.

3.CO emission

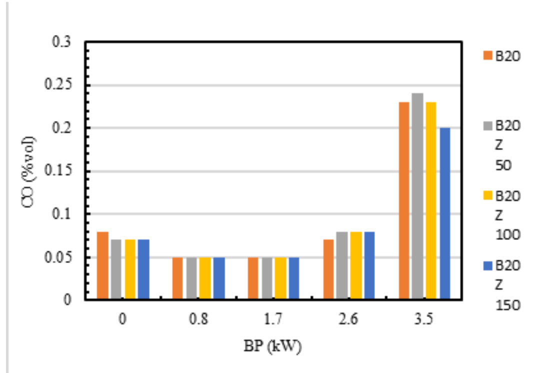


Fig 6: Variation of CO emission with respect to brake power

From the fig 7 at full load CO emission of B20+150 ppm of zinc oxide has very lees emission compared with other blends of B20 Bio diesel. At full load CO emission of B20+150 ppm of zinc oxide decreases by 15% compared to B20 neat blend. The decrease in CO emission is due to by the addition of ZnO nano particle as it is an oxidation catalyst it promotes the combustion characteristics of the blended fuel.CO present is converted to CO_2.

4.CO_2 emission

It is clear from the fig 8 that CO_2 emission of B20+150 ppm of zinc oxide shows less the CO_2 emissions compared with other blends of B20 biodiesel and other nano additive blends of zinc oxide and copper at the full load and 75% of load and at full load. The CO_2 emission of B20+150 ppm of zinc oxide decreases by 5.20% compared to B20 neat blend. By the addition of ZnO nano particle as it is an oxidation catalyst it promotes the combustion characteristics fuel. Due this their decrease in CO_2 emission.

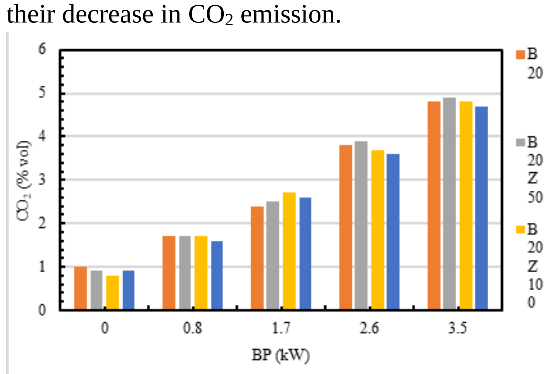


Fig 9: Variation of CO_2 emission with respect to brake power

5.HC emission

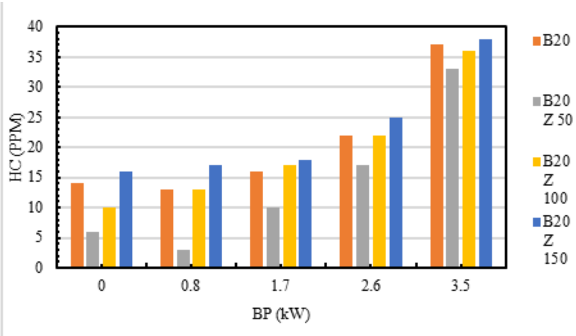


Fig: 10 Variation of HC emission with respect to brake power

It is clear from the fig: 11 that HC emission of B20+50 ppm of zinc oxide shows less the HC emissions compared with other blends of B20 biodiesel and other nano additive blends of zinc oxide at all the other load. By the addition of nano particle with the biodiesel the ignition delay is reduced, because of the good combustion of the nano fuel blends.

6.NO_X emission

It is clear from the fig 12 that NO_X emission of B20+150 ppm of zinc oxide shows less the NO_X emissions compared with other blends of B20 biodiesel and other nano additive blends of zinc oxide at all of load

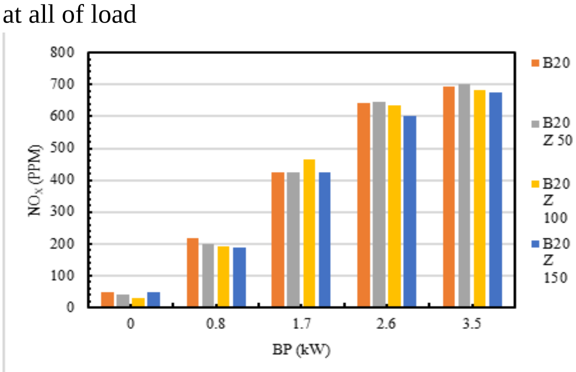


Fig 13 variation of NO_X emission with respect to brake power

7.Smoke emission

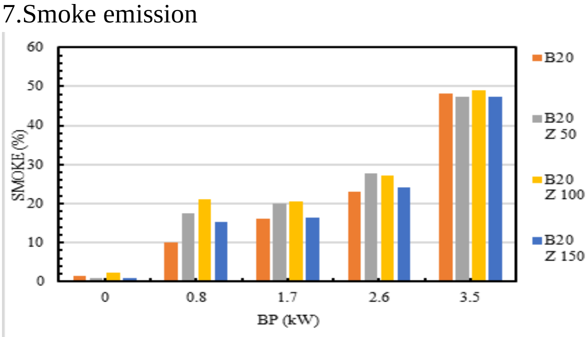


Fig 9: Variation of smoke with respect to brake power

It is clear from the fig 9 that smoke emission of B20+50 ppm of zinc oxide shows less the smoke emissions compared with other blends of B20 biodiesel and other nano additive blends of zinc oxide at all the other load. Because of good thermal stability of the nano fuel, which progress the decrease in the concentration of HC, CO and CO2 emissions of the fuel and good combustion of nano results in a lower smoke emission.

VI. CONCLUSION

The performance and emission of diesel engine using B20 biodiesel and other nano blended fuels were analyzed based on that following conclusion are obtained.

- Brake thermal efficiency of B20+150 ppm of zinc oxide nano particle shows the highest efficiency compared with the B20 other blends at 75% of load and there is an increase in 2.62% of BTE when compared to B20 biodiesel, the of BSFC of B20+150 ppm of zinc oxide decrease by 8.52% compared B20 bio diesel,
- The carbon dioxide emission of B20+150 ppm of zinc oxide decreases by 5.20% compared to B20 neat blend, at full load CO emission of B20+150 ppm of zinc oxide decreases by 15% compared to B20 neat blend.
- The HC emission of B20+50 ppm of zinc oxide shows less the HC emissions compared with other blends of B20 biodiesel and other nano additive blends of zinc oxide at all of load.
- The NOX emission of B20+150 ppm of zinc oxide shows less the NOX emissions compared with other blends of B20 biodiesel and other nano additive blends of zinc oxide at all of load.
- In the overall analysis of experiment, the blend of B20+150 ppm of ZnO is found more favorable compared with other blends of the experiment.

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