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Effect of Nanoparticles Proportions on the Performance and Emission Characteristics of CI Engine Fueled with Rice Bran Oil Biodiesel

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***Abstract* - Experimental investigations are carried on a single cylinder CI engine having rated power of 3.5 kW at constant speed of 1500 rpm at varying loads and the effect of concentration of nanoparticles in rice bran oil biodiesel and diesel blends are presented. A blend of 30% rice bran biodiesel and 70% diesel by volume (B30) is considered for study. Nano particles of copper metal at 50, 100 and 150 ppm are added to the B30 blend. Performance and emission characteristics are evaluated for the blends and results are compared with that of diesel. It is found that brake thermal efficiency of B30 blend with copper nanoparticle of 150 ppm is 7.06% higher than of diesel at full load. Smoke, carbon monoxide, unburned hydrocarbon and nitrogen oxide emissions is reduced by 9.2%, 25.9%, 17.5% and 6.4% with that of diesel for B30 Cu 150 ppm.**

***Index Terms* - Biodiesel, emissions, nanoparticles, proportions, performance, rice bran biodiesel, transesterification.**

I.INTRODUCTION

As concerns are growing towards environmental pollution as well as diminishing petroleum resources it is inevitable to country like India to depend on alternate fuels like biodiesel as new alternative dependable fuels [1,2]. Rice bran oil is non-conventional low grade oil but has many valuable by products such as tocopherols and tocotrienols, squalene, oryzanol, rice bran lecithin, rice bran wax, phytosterols, glycerin, soap water and deodorizer [3] which may be separated from the oil and the oil may be used to produce the biodiesel which intern is cost effective. Biodiesel are producing rated capacity at lower efficiency with increase in exhaust emissions. To improve the performance and emission characteristics of biodiesel nanoparticles are added in small quantities.

Performance of an engine depends on how the nanoparticles are dispersed in base fuel, amount of nanoparticles and the operating parameters of the CI engine. ZnO nanoparticles at a more quantities shows the positive effect on performance, on other hand nanoparticles like CNT, Al_2O_3, Al and CeO_2 shows positive effect at even in small quantities [4].

The copper nanoparticles showed positive effect on the performance, emission and combustion characteristics of CI engine with calophyllum inophyllum biodiesel [5]. In an experiment the B30 blend of rice bran biodiesel showed the better performance and emission characteristics for CI engine [6]. Varying proportions of nanoparticle have effect on the performance on the engine. It is observed that, 25 to 150 ppm nanoparticle at varying concentrations have shown improvement in performance and reduction in emissions [7-13].

In present investigation 30% rice bran oil blend with diesel is selected as fuel and copper nanoparticles at varying proportions are added to the B30 blend. The performance and emission characteristics are evaluated and results are compared with that of diesel.

II. PREPARATION OF BIODIESEL AND DISPERSION

A. Transesterification

The crude rice bran oil is obtained by crushing and expelling oil from outer layer of rice. The transesterification is carried out in single stage process as the crude rice bran oil is pretreated to attain FFA value less than four (4). Then pre-treated oil of one liter is mixed with 300 ml methanol and 5-7 grams of NaOH is added to three neck-flask and heated to 60-65 degree Celsius for 3 hours. Condenser coil is supplied with water to condense the methanol and continuous stirring is done till the color changes and then it is transferred to separating funnel for overnight. Glycerin which is heavier collected at the bottom leaving biodiesel at the top. Glycerin is removed and biodiesel thus obtained is water washed and heated to remove the moisture.

B. Blends preparation and nanoparticles dispersion

The B30 blend is made by mixing 30% biodiesel and 70% diesel by volume. The copper nanoparticles are added to the B30 biodiesel in the proportions of 50, 100 and 150 ppm. Table 1 shows the properties of the nanoparticles. Its observed that particles size are 30-50nm, specific surface area is of the order 16m^2/g and bulk density is 0.2g/cm^3. The Fig. 1 shows the scanning electron microscopic image which verify the particles size of copper nanoparticles. The average size of particles is 30-50nm in diameter as shown.

Table 1: Properties of copper nanoparticles

Sl No.	Properties (Tested)	Results
1	Particle size	30-50 nm
2	SSA	16 m^2/g
3	Bulk density	0.2g/cm^3

For uniform and effective dispersion of nanoparticles in biodiesel blends ultrasonicator is used. In which high frequency vibrations are used to disperse the nanoparticles in the solution uniformly. The blends are prepared by adding 50, 100 and 150 ppm of copper nanoparticles in the B30 blends i.e. 50 mg/l, 100 mg/l and 150 mg/l respectively and sonication process is carried out for one hour. Further magnetic stirrer is used for three hours to avoid agglomeration.

Table 2 shows the properties of diesel, biodiesel blend and biodiesel with nanoparticles. Density of biodiesel blend with and without copper nanoparticles are 1.5% higher than that of diesel. Flash point and fire points of biodiesel blends with and without copper nanoparticles are 27-29% higher than that of diesel. However calorific value of biodiesel blends and samples with nanoparticles are marginally lower than that of diesel. Viscosity of diesel and all samples under test are well comparable with each other. This

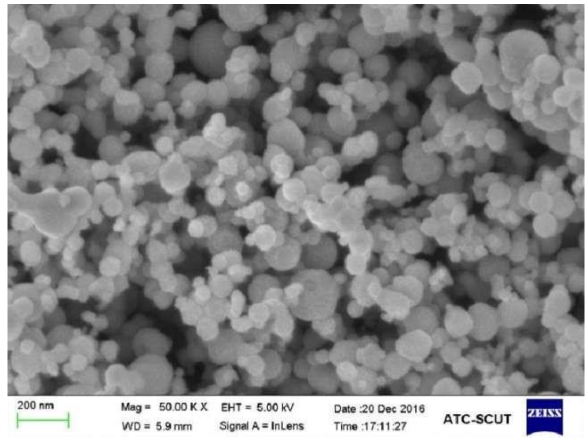

Fig.1 : Scanning electron microscope (SEM) image of copper nanoparticles

viscosity is sufficient for proper atomization of fuels under test.

Table 2: Properties of diesel, biodiesel blend and biodiesel with nanoparticles

Properties	Diesel	B30	B30 Cu 50 ppm	B30 Cu 100 ppm	B30 Cu 150 ppm
Density (kg/m^3)	830	843	843	843	843
Flash point in °C	62	86	86	86	86
Fire point in °C	65	92	92	92	92
Calorific value (kJ/kg)	40500	39966	39966	39966	39966
Viscosity at 40°C (mm^2/s)	3.7	4.7	4.7	4.7	4.7

III. EXPERIMENTAL SETUP

In agriculture applications a single diesel engine is most commonly used in India. Hence in this experiment Kirloskar TV1 engine is selected. The engine is a single cylinder four stroke water cooled having 3.5 kW rated capacity at 1500 rpm. The detailed specifications are shown in Table 3. Eddy current dynamometer is used for measurement of brake power, AVL 437 standard smoke meter is used to measure smoke. AVL 444N five gas analyzer is used to measure, CO, unburned hydrocarbons, O_2 and NO emissions. Fig. 2 shows the schematic diagram of engine setup used to carry out the experiment.

Table 3: Engine specifications

Sl.No.	Components	Specification
1	Engine	Kirloskar TV1
2	Engine type	IC Engine.
3	Ignition type	Compression Ignition.
4	Fuel type	Diesel.
5	Power	3.50kW
6	Revolutions	1500 rpm
7	Number of cylinder	1 Cylinder
8	Stroke	4 Stroke
9	Running at	Constant speed
10	Cooling	Water cooled
11	Cylinder Bore	87.50 mm
12	Stroke Length	110 mm
13	Connecting Rod Length	234 mm
14	Compression Ratio	17.5
15	Swept volume	661.45 cc
	Performance parameter:	
16	Orifice Diameter	20 mm

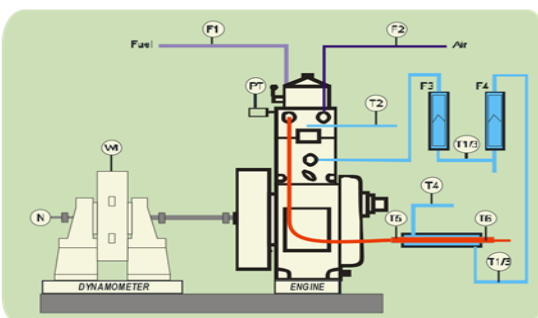

Fig. 2: Schematic diagram of engine setup IV.

METHODOLOGY

The experiment is conducted at the constant speed of 1500 rpm and at varying loads of 0%, 25%, 50% and 100%. The base line data were obtained by using diesel at varying loads. Further the experiment is conducted with B30, B30 Cu 50 ppm, B30 Cu 100 ppm and B30 Cu 150 ppm blends. For every reading the engine was given sufficient time to get steady state readings. The performance evaluation is done by calculating brake thermal efficiency, brake specific fuel consumption and exhaust gas temperature. The emission characteristics are evaluated by measuring smoke, CO, unburnt hydro carbon, CO_2, and NO emissions. Results obtained by using biodiesel blend with and without nanoparticles are compared with that of baseline diesel values.

V. RESULTS AND DISSCUSION

A. Performance characteristics

1. Brake thermal efficiency.

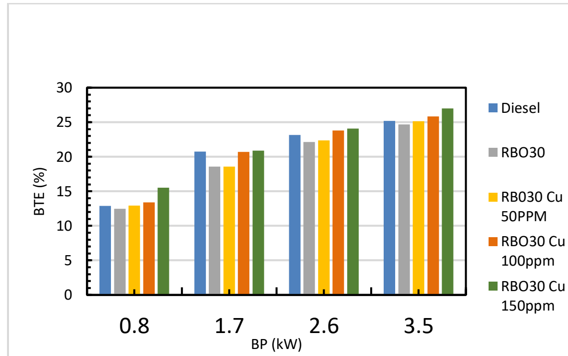

Fig. 3: Variations of brake thermal efficiency with respect to brake power.

Fig. 3 shows the variation of brake thermal efficiency with brake power for all fuels under test. Brake thermal efficiency of all fuels under test increases with increase in load as load increases quantity of the fuel fired, obviously this increases thermal efficiency. Brake thermal efficiency of B30 is 24.96% at full load, which is lower than that of diesel which is 25.2%. This attributes to bigger drop sizes of B30 blend due to higher viscosity and density. By adding nanoparticles, it is found that brake thermal efficiency increases steadily with increase in percentage of copper nanoparticles. At full load the maximum efficiency of B30 Cu 150 ppm is 26.98% against 25.2% of that of diesel. Which is 7.06% higher than that of base line diesel. At full load thermal efficiency of B30 Cu 50 ppm and B30 Cu 100 ppm are 25.16% and 25.85% respectively. This increase in thermal efficiency attributes to increase in reaction surface area by adding nanoparticles and proper atomization.

2. Brake specific fuel consumption.

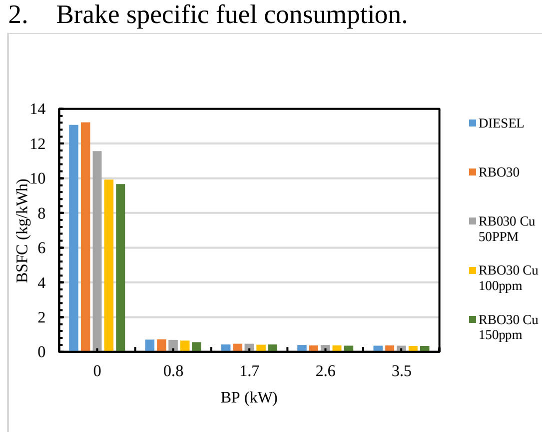

Fig. 4: Variation of brake specific fuel consumption with brake power.

The Fig. 4 shows variation of brake specific fuel consumption of all fuels under test with brake power. Brake specific fuel consumption is inverse/reciprocal of brake thermal efficiency. Brake specific fuel consumption decreases with increase in load and becomes minimum at full load for the present test. Brake specific fuel consumption of B30 Cu 50 ppm, B30 Cu 100 ppm, B30 Cu 150 ppm are respectively 0.35, 0.34 and 0.33 kg/kWh, against 0.35 kg/kWh of that of diesel at full load. Addition of nanoparticles decreases brake specific fuel consumption and minimum occurs at B30 Cu 150 ppm blend at full load. Obviously this attributes to increase in the spray cone angle which improves the dispersion of the fuel and enhanced droplet propagation. The another main reason for lower brake specific fuel consumption of the nanoparticles fuels is due to its higher surface to volume ratio.

3. Exhaust gas temperature (EGT).

The Fig. 5 shows variation of exhaust gas variations with brake power for the fuels under test. It is observed that exhaust gas temperature slightly increases with load. Exhaust gas temperature of B30 Cu 150 ppm at full load is 312°C against 296°C of that of diesel. This marginal increase in exhaust temperature attributes to proper and complete combustion due to the improved atomization due to addition of nanoparticles and inbuilt oxygen content in biodiesel.

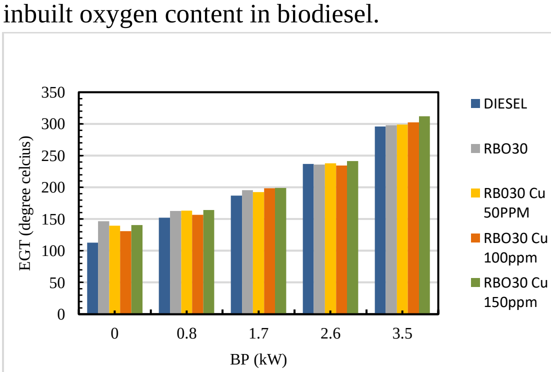

Fig. 5: Variation of exhaust gas temperature with respect of brake power.

Therefore, there is a little higher exhaust emissions losses due to addition of nanoparticles. For B30 Cu 50 ppm and B30 Cu 100 ppm falls in between diesel and B30 Cu 150 ppm.

B. Emission characteristics

4. Smoke emission

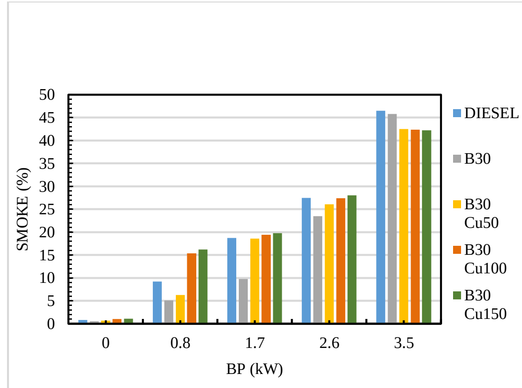

Figure 6: Variation of smoke emission with respect to brake power.

The variation of the smoke emission with brake power for all fuel blends tested are shown in the Fig. 6. As the load increases the smoke emissions increases because quantity of fuel fired increases with load. At higher loads fuel mixture is very rich and which makes combustion incomplete. B30 blend has lower smoke emissions at all loads this could be due to inbuilt oxygen present in the biodiesel which reduces ignition delay. The smoke emission reduces by adding nanoparticles to biodiesel compared to that of diesel. At full load smoke emission is reduced by 1.5%, 8.6%, 8.8% and 9.2% for B30, B30 Cu 50 ppm, B30 100 ppm and B30 150 ppm respectively as compared to diesel. The decrease in smoke is due to the higher reaction surface area, proper atomization, improved fuel and air mixing and rapid evaporation rate, which causes the reduction in smoke emissions.

5. Carbon monoxide

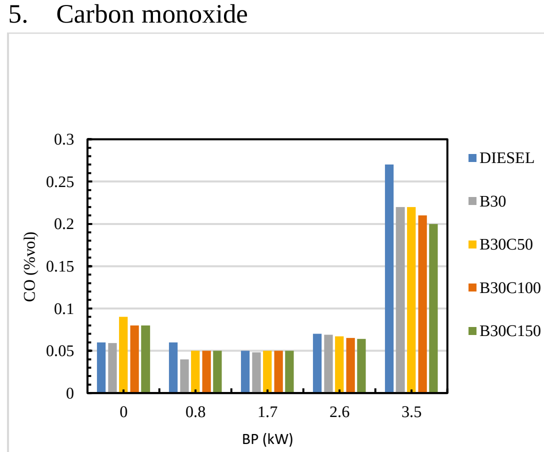

Fig. 7: Variation of carbon monoxide with respect to brake power.

The Fig. 7 shows the variation of carbon monoxide with brake power for all fuels under test. It is observed that the carbon monoxide emissions of B30 is lower than that of diesel at all loads. This is due to inbuilt oxygen present in biodiesel, which is readily available for combustion by reducing ignition delay. At no load carbon monoxide emission for B30 Cu 50 ppm, B30 Cu100 ppm and B30 Cu 150 ppm biodiesel blends is higher than that of diesel. This is because of low temperature of engine cylinder and quenching effect. However, for higher loads biodiesel blends with nanoparticles shows lower carbon monoxide emissions. At full load B30 Cu 150 ppm blend showing a maximum reduction of 25.9% compared to diesel. This is due to the increased surface area to volume ratio available for reaction with the oxygen present in the biodiesel.

6. Unburnt hydrocarbons emissions

The Fig. 8 shows the variation of unburned hydrocarbon emissions with brake power for all tested fuels. The unburned hydrocarbon emission increases with increase in load for all test samples.

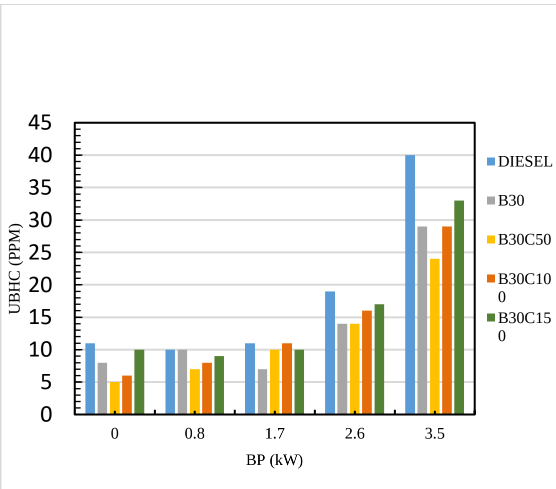

Fig. 8: Variation of unburned hydrocarbons with brake power.

As the load increases quantity of fuel fired also increases which makes fuel air mixture rich. At higher loads due to non-uniform mixing of fuel air mixture, quenching, blow by and crevice flow the unburned hydrocarbon emissions are higher. At lower nanoparticles concentrations unburned hydrocarbon emissions are significantly lower than that at higher concentrations. This attributed to quenching, blow by and crevice flow. At full load there is 27.5%, 15%, 27.5% and 17.5% reduction for B30, B30 Cu 50 ppm, B30 Cu 100 ppm and B30 Cu 150 ppm blends respectively as compared to diesel.

7. Nitrogen oxide emission

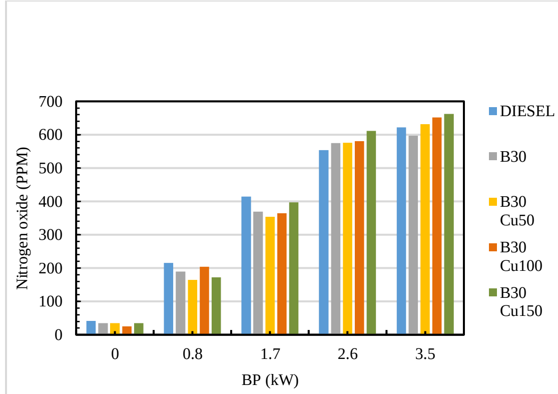

Fig. 9: Variation of nitrogen oxide with respect to brake power.

The Fig. 9 shows the variation of nitrogen oxide emissions with respect to brake power for all blends. Nitrogen oxide emission depends on concentration of oxygen and temperature of product of combustion in the cylinder. Either higher concentration of free oxygen, higher temperature of the gas or combination of both leads to formation of nitrogen oxides. At lower loads such as 0%, 25% and 50% loads the emission of nitrogen oxides for biodiesel and its blends with nanoparticles is lower than that of diesel. This is due to lower temperature of gas in the cylinder. At higher loads i.e. 75% and 100% loads the nitrogen oxide formation is increased due to higher temperature of product of combustion in engine cylinder. At full load nitrogen oxide emission is increased by 1.6%, 4.8% and 6.4% respectively for B30 Cu 50 ppm, B30 Cu 100 ppm and B30 Cu 150 ppm as compared to diesel.

VI. CONCLUSION

The experiments are conducted on a single cylinder direct injection four stroke diesel engine which was fueled with rice bran biodiesel and copper nanoparticles dispersed at varying concentrations i.e. 50ppm, 100ppm and 150ppm to show the effect varying concentration of nanoparticles on performance and emission characteristics of diesel engine and test are conducted at constant speed of 1500 rpm and varying load i.e. 0%, 25%, 50% and 100%. From the experimental evaluation/analysis the following conclusion are obtained,

1. Brake thermal efficiency is increased by adding nanoparticles to biodiesel blend. Brake thermal efficiency for B30 Cu 150 ppm is 7.06% higher than that of diesel at full load.

2. Increase in concentration of nanoparticles in biodiesel blends increases brake thermal efficiency of the engine. For the blends under test B30 Cu 150 ppm performed better than other two combinations respectively B30 Cu 50 ppm and B30 Cu 100 ppm.
3. Brake specific fuel consumption decreases as the nanoparticles concentration increases in the blend. For B30 Cu 150 ppm blend brake specific fuel consumption is 0.33 kg/kWh against that of diesel which is 0.35 kg/kWh at full load.
4. There is a marginal increase in exhaust gas temperature and subsequent exhaust losses for B30 Cu 150 ppm compared to that of diesel.
5. The smoke emission reduces by adding nanoparticles to biodiesel. At full load smoke emission is reduced by 9% for B30 Cu 150 ppm blend compared to diesel.
6. At zero load carbon monoxide emissions of all blends with and without nanoparticles are higher than that of diesel. However, as load increases carbon monoxide emissions are significantly decreased.
7. Unburned hydrocarbon emissions are lower for all biodiesel blends with and without nanoparticles at all loads. Increasing concentration of nanoparticles in biodiesel increased unburned hydrocarbon emissions.
8. At higher loads nitrogen oxide emissions for biodiesel blends with and without nanoparticles are higher.

Abbreviations and Acronyms

B30– biodiesel 30% and 70% percent diesel.

B30 Cu 50ppm - 50ppm nanoparticles biodiesel 30% and 70% percent diesel.

B30 Cu 100ppm -100ppm nanoparticles biodiesel 30%and 70% percent diesel.

B30 Cu 150ppm - 150ppm nanoparticles biodiesel 30% and 70% percent diesel.

BTE - Brake thermal efficiency.

BSFC - Brake specific fuel consumption.

CO -Carbon monoxide.

CO_2 -Carbon dioxide.

EGT – Exhaust gas temperature.

HRR – Heat release rate.

NO - Nitrogen oxide emissions.

PPM - parts per million.

SSA – Specific surface area.

UBHC - Unburned hydrocarbons.

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