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# Performance and Emission Characteristics of CI Engine using Biodiesel (Cotton Seed Oil) Blends with Titanium Oxide

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**ABSTRACT:**

*In this work, experimental investigation was carried out to test the performance and emission characteristics of a CI engine using diesel and cotton seed oil methyl ester blended fuel (COSME20) along with titanium oxide nano particles as an additive in biodiesel blends. The titanium oxide nanoparticles promote the combustion process that results in more oxidation of CO and reduces HC emission. The engine test was conducted with various blends of diesel and biodiesel with and without nanoparticles, namely B20 (20% biodiesel + 80% diesel), BN20 (20% biodiesel + 80% diesel + 20ppm), BN40 (20% biodiesel + 80% diesel + 40ppm) at different loads. The test results showed that the addition of titanium oxide nanoparticles in diesel and biodiesel blends improved combustion and reduced the exhaust gas emissions significantly.*

**KEYWORDS:**

*Biodiesel; Titanium oxide nanoparticle; Diesel engine; Performance and emissions*

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**NOMENCLATURE:**

| | |
|---|---|
| BSFC | Brake specific fuel consumption |
| BP | Brake power |
| ME | Mechanical efficiency |
| BTE | Brake thermal efficiency |
| CO | Carbon monoxide |
| HC | Hydrocarbon |
| NOx | Oxides of nitrogen |
| PPM | Parts per million |
| COSME | Cotton seed oil methyl ester |
| COSME20 | 80% diesel + 20% biodiesel |
| TIONP | Titanium oxide nanoparticles |
| TIONP20 | Titanium oxide nanoparticles of 20 ppm mixed with COSME20 |
| TIONP40 | Titanium oxide nanoparticles of 40 ppm mixed with COSME20 |

## 1. Introduction

Diesel engines are widely used for better efficiency and low fuel consumption when compared with petrol engines. Diesel and biodiesel blending methods can be used for the diesel engine without modification. At full load condition all emissions were decreased. Fangrui.et. al [1] studied that the variation in engine speeds and loads were decreased the HC and increased CO emissions. Pollutant levels are decreased using biodiesel. Lee et al [2] studied the use of cotton seed oil methyl ester in the diesel engine. Local air contamination caused by using fuels with increased $CO_2$ emissions will make local air pollution stronger and speed up the worldwide warming troubles. Nabi et al [3] explored clean biodiesel as a substitute for the fossil fuel. Biodiesel can be easily produced in rural areas. Selvam et al [4] studied that the diesel engine using biodiesel has reduced CO, $CO_2$ and particulate matter whereas increased the $NO_x$ emissions.

Sulphur is not present in the biodiesel. Severe emissions legislation has been forced worldwide on the $NO_x$, smoke and particulate substance emitted from diesel engines. The different fuel properties in which particulate emissions like sulphur content, density, volatility in the fuel can be changed with the use of fuel additives. Biodiesel degrades rapidly in the surroundings and nontoxic. Every day increase in the oil prices could considerably reduce the cost of diesel fuel and increase the production of biodiesel. Premanand et al [5] concluded that the addition of nanoparticles with biodiesel reduced the ignition delay and burning times of the fuel. John et al [6] concluded that by adding nanoparticles to the biodiesel improved the combustion properties of the fuels and reduced the exhaust gas pollutants. Praveenkumar et al [7] studied about the burning and control of the emission knocking of the engine.

## 2. Materials and methods

### *2.1. Preparation of biodiesel*

Biodiesel consists of methyl esters and fatty acids removed fully through the transesterification process effect of triglycerides of vegetable oils using methanol as catalysts. One of the general methods used to decrease the oil viscosity in the biodiesel manufacturing is called transesterification. Magnetic stirrer equipment, thermo-meter, and beaker were used for transesterification process. Raw material is cotton seed oil, methanol and potassium hydroxide. Cotton seed oil was measured to a capacity of 1000ml filled into the beaker. Aalam et al [8] carried out an experimental investigation by heating the cotton seed oil in the magnetic stirred electric heater for about an hour. Then, at a speed of 1000rpm it was stirred and warmed up at 60°C to the oil. 250ml of Methanol and 5g of potassium hydroxide was dissolved by forceful stirring. Hot oil was taken in the bottle for 24 hours to settle down methyl ester at the top and glycerin at the bottom. At 80°C distilled water was added to double volume with methyl ester and after 15 min of stirring, glycerine settles down again. This procedure was repeated until the ester layer was cleared.

### *2.2. Preparation of biodiesel with addition of nanoparticles*

COSME20 biodiesel was prepared by using blending method in the ratio of 80% diesel and 20% biodiesel. Biodiesel blended separately by adding titanium oxide nano-particles in proportion of 20ppm and 40ppm in an ultrasonicator for mixing properly. Properties of diesel, biodiesel, 20% biodiesel and 80% diesel blends are shown in Table 1.

**Table 1: Properties of diesel, biodiesel and COSME20**

| Properties | Diesel | COSME | COSME20 |
|---|---|---|---|
| Kinematic viscosity @ 40°C in Cst | 2.51 | 5.7 | 3.54 |
| Density (kg/m$^3$) @ 15 (°C) | 834 | 885 | 852 |
| Cetane number | 50 | 52 | 52 |
| Flash point (°C) | 50 | 161 | 160 |
| Specific gravity @ 27 (°C) | 0.840 | 0.882 | 0.870 |

## 3. Experimental set up and test procedure

The experiment was conducted using four strokes, air cooled single cylinder diesel engine. Details of the engine specification are given in Table 2. The AVL smoke meter 415 used to measure the smoke density. AVL - DIGAS 444 five-gas analyzer is used to measure the rest of the pollutants such as $NO_x$, HC and CO. The experimental setup is illustrated in Fig. 1.

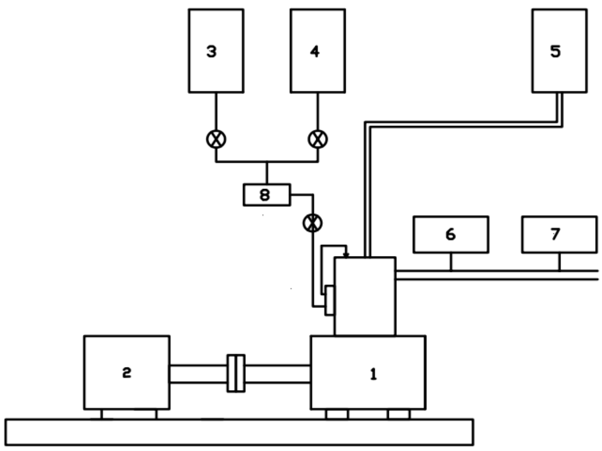


**Fig. 1: Experimental setup**

*1. Engine; 2. Electrical dynamometer; 3. Diesel fuel tank; 4. Biodiesel fuel tank; 5. Manometer; 6. Gas analyzer; 7. Smoke meter; 8. Fuel control valve*

**Table 2: Engine specification**

| Parameter | Value |
|---|---|
| Bore diameter | 87.5 mm |
| Stroke | 110 mm |
| Compression ratio | 17.5 : 1 |
| Maximum power | 4.4kW |
| Speed | 1500rpm |
| Dynamometer | Swing field electrical type |
| Injection timing | 23° (before TDC) |
| Injection pressure | 200 bar |

## 4. Results and discussion

### *4.1. Engine performance*

Fig. 2 shows the variation of brake power with respect to specific fuel consumption (SFC) for biodiesel and biodiesel with titanium oxide nanoparticles. Fuel consumption reduces for an increase in the titanium oxide dosing levels. Jothi Thirumal et al [9] studied the development for increasing the efficiency of the fuel and emissions reduction. Diesel fuel and 20ppm titanium oxide fuel are almost performed similar while the 40ppm titanium oxide nanoparticles fuel proved to be a significant in terms of SFC reduction. The addition of TIONP40 ppm resulted in 4% reduction in SFC at maximum brake power. Fig. 3 shows the brake thermal efficiency (BTE) with respect to the brake power for biodiesel (COSME20) and biodiesel with TIONP. The BTE of the diesel engine is increased with TIONP in the fuel. The titanium oxide nanoparticles in the biodiesel blend supports complete combustion. The thermal efficiency rises with the dosing level of nanoparticles. The BTE of COSME20 with TIONP40 ppm was better than biodiesel. A 4% increase in BTE was recorded for COSME20 with TIONP40.

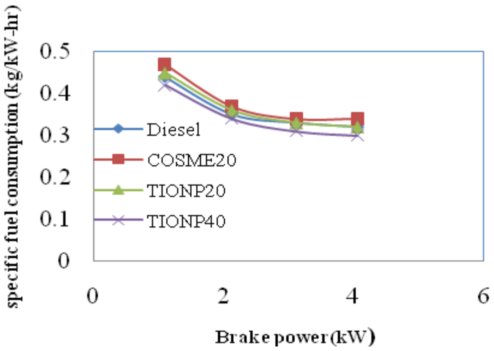


**Fig. 2: SFC vs. Brake power**

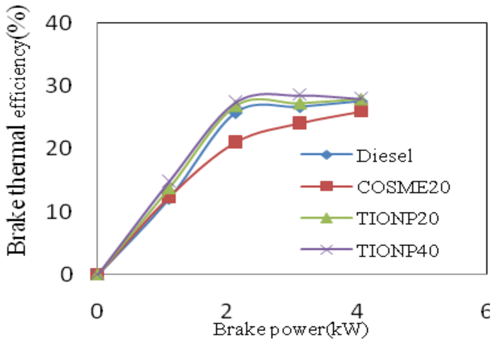


**Fig. 3: Brake thermal efficiency vs. Brake power**

### *3.2. Emission parameters*

Fig. 4 shows that the biodiesel with addition of nanoparticles increased the level of oxygen. Oxygen substance of fuel is the most important cause for decreased HC emissions due to complete combustion. HC emissions were reduced in the biodiesel with addition of nanoparticles. If the brake power is increased HC emissions were increased generally but due to addition of titanium oxide nanoparticles, HC values got from the graph are 92ppm, 81ppm and 71ppm for COSME20, TIONP20 ppm and TIONP40 ppm.

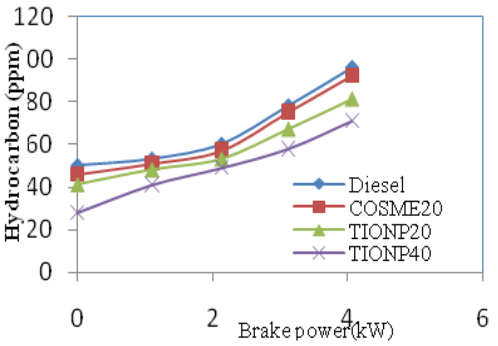


**Fig. 4: HC Emissions vs. Brake power**

Fig. 5 shows the variation of carbon monoxide emission with brake power. TIONP have high area of surface contact resulting in increased reactivity which reduced the ignition delay period. Ghassan et al [10] studied diesel blended biodiesel had decreased the CO emission at lower brake power. For the full brake power, CO emission decreased considerably due to use of TIONP additive. The CO reductions are in the order of about 45%, 35% and 26% for the cases of COSME20, TIONP 20 ppm and TIONP 40 ppm.

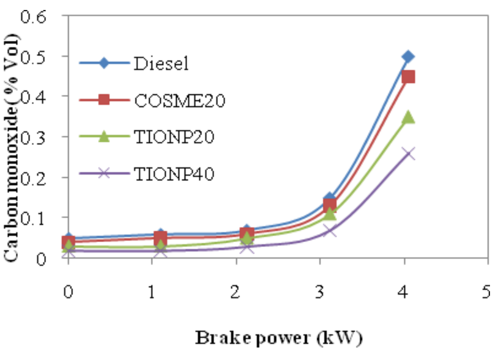


**Fig. 5: CO Emissions vs. Brake power**

Fig. 6 shows the variation of smoke with respect to brake power for biodiesel and biodiesel with addition of nanoparticles. When brake power increases, the smoke density slowly increases in all cases. For COSME20, the smoke density change from zero brake power to maximum brake power was higher than diesel fuel. Addition of nanoparticles considerably decreases the smoke concentrations with respect to biodiesel for all values of the brake power. The smoke concentrations at maximum brake power are 53, 68, 62, 59 HSU for diesel, COSME20, TIONP20 and TIONP40 which is comparable to the trend of diesel fuel. The smoke density decreased with an increase in TIONP.

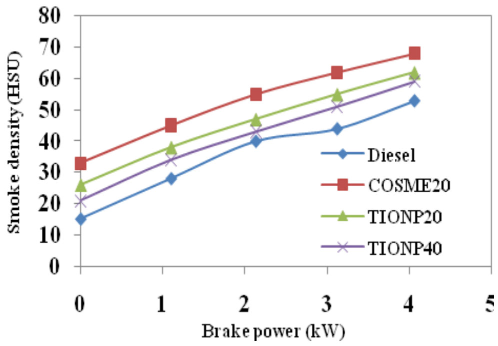


**Fig. 6: Smoke density vs. Brake power**

Fig. 7 shows the $NO_x$ emissions without and with the addition of nanoparticles with COSME20. $NO_x$ emissions steadily rise with the addition of nano particles in all the cases. $NO_x$ emission is mostly depended on temperature. TIONP20 resulted in lower $NO_x$ emission than other concentrations. $NO_x$ emission of COSME20 without addition of TIONP was 855ppm. For the dosage of 20ppm TIONP, $NO_x$ emission was 925ppm and for dosage of 40ppm TIONP $NO_x$ emission was 990ppm.

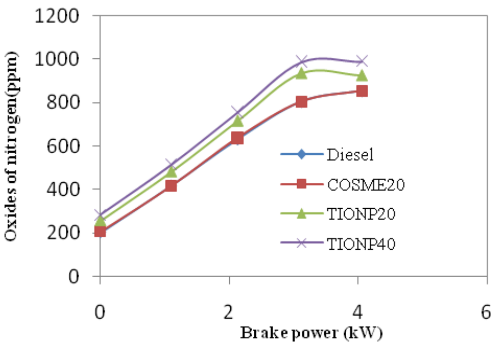


**Fig. 7: NOx Emissions vs. Brake power**

## 5. Conclusion

The performance and emission of diesel engine using biodiesel (COSME20) with TIONP20 ppm and TIONP40 ppm were analyzed. The specific fuel consumption for the COSME20 was higher than neat diesel at the entire brake power. SFC was decreased for an increase in the dosing level of TIONP. The BTE of COSME20 is less than neat diesel at all the brake power and a small improvement can be achieved by using TIONP with COSME20. The CO emission reduces with the use of TIONP in COSME20. The addition of TIONP in COSME20 fuel reduces the HC emissions in comparison with neat diesel. The quantity of smoke emission is higher for COSME20 than the neat diesel. The addition of TIONP in COSME20 the smoke emission was further reduced in comparison with biodiesel. The $NO_x$ emission is lesser for the neat diesel than the COSME20 blend. The $NO_x$ emission was increased with the addition of TIONP with biodiesel.


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