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Experimental Study on Effect of Additives on the Performance and Emission Characteristics of Biodiesel Blend Fueled CI Engine

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Abstract-*The Diesel engine is the most efficient type of power sources among all types of internal combustion engines. Conventional fossil fuels cause more pollution this leads to search for environmental friendly and renewable fuels. Biodiesel is one of the alternative source of fuels Biodiesel contains virtually no sulphur or aromatics, and use of biodiesel in a conventional Diesel engine results in substantial reduction of unburned hydrocarbons, carbon monoxide and particulate matter but increase NO_x emission, poor low temperature fuel properties. To overcome this draw back metal oxide nanoparticle are added to biodiesel. Due to their special properties like higher thermal conductivity, chemical properties enhanced properties of these additives. By addition of nanoparticle promotes better combustion is the cause for reduction of hydrocarbon emission.*

In the present work, experimental investigation was carried out to study the effect on performance characteristics and emissions (HC, CO and NO_X) of diesel engine with Pongamia biodiesel (B20) and Titanium oxide nanoparticle (150ppm, 250ppm and 350ppm) additives with Diesel and the measured values are compared with neat diesel.

Keywords- Diesel engine, Biodiesel, Titanium oxide Nanoparticles, Transesterification, Combustion, Emission.

1. INTRODUCTION

Diesel engine plays a vital role in power generation, transportation and industrial activities. The reason for the surge in diesel popularity is simple better fuel economy at minimal expense Honge oil is also called Karanja oil. Its botanical name is Pongamiapinnata, belongs to family ofLeguminaceae or papilionaceae. It can grow on most soil types ranging from stony to sandy to clayey. It does not grow well in dry sands. The seeds are usually elliptical, 1.7-2cm wrinkled with reddish brown leathery test a. India has about 80-100 million hectares of waste land, which can be used plantation of Pongamia and others. The viscosity of Pongamia oil is very high to be directly used as diesel fuel substitute. By the transesterification process the viscosity of is reduced [1]. Among the edible and non- edible vegetable oils, the non-edible oils such as jatropha [2], pongamia [3]etc, are economical as biodiesel for its less consumption in domestic purposes. It is widely agreed that biodiesel decreases the emissions of hydrocarbons (HC), carbon monoxide (CO), particulate matter (PM) and sulphur dioxide (SO_2)[4-8]. Muthusamy Sivakumar et al. [9] concluded that aluminium oxide nanoparticles is efficient and enhances the engine performance, combustion characteristics and reduces the exhaust emissions of the diesel engine. Senthil Ramalingam et al. [10] concluded that antioxidants additives also have effect in reducing the NOx emission from the engine without affecting the engine performance and emission characteristics. So, maximum of 10% reduction in NOx emission can be achieved by the addition antioxidant with biodiesel. M. Srinivasa Rao et al.[16] were carried out experiment for neat diesel, Jatropha biodiesel (BD), water biodiesel emulsion fuels (BD5W, BD10W) and AlO(OH) nanoparticles blended water biodiesel emulsion fuels (BD5W25, BD5W50, BD5W100, BD10W25, BD10W50 and BD10W100) NO_x and smoke opacity are reduced by 42% and 18% respectively for BD10W100 fuel compared to biodiesel, BTE is improved by 6% and emission reduction NO by 27% and smoke opacity by 8% for BD10W fuel compared to biodiesel. Syed Aalam et al. [18]were carried out experiment using diesel with 25 percentage of zizipus jujube methyl ester blended fuel (ZJME25). Along with this ZJME25 aluminum oxide nanoparticles were added as additive in mass fractions of 25 ppm (AONP 25) and 50 ppm (AONP 50) the heat release rate increases with the addition of AONP in biodiesel blend. The addition of AONP accelerates earlier initiation of combustion and cause for the higher heat release rate when comparing with ZJME25.NagarajBanapurmath et al. [22] were carried outExperimental investigations to determine performance, emission, and combustion characteristics of diesel engine operated on diesel, Honge Oil Methyl Ester (HOME) and 25ppm and 50ppm silver nano-particles blended fuels, HOME resulted in poor performance in terms of reduced brake thermal efficiency. However HOME performance was enhanced with silver nano-particle additives. Performance was further improved with higher dosing level of silver

nano-particles in biodiesel. Based on above literature attempt as been made to study the potential effects of Pongamia biodiesel and Titanium oxide nanoparticle blend on engine performance and Emissions.

2. MATERIAL AND METHOD

2.1 Pongamia biodiesel

The biodiesel used in this study is obtained from pongamia oil by transesterification process. It is the process by which fatty acid is converted into its corresponding ester. The mixture of pongamia oil, methanol and sodium hydroxide (NaOH) as catalyst is taken in the reaction chamber fitted with condenser and thermometer. The entire mixture is heated at a temperature of65 ^{o}C for 2 hours and then cooled down to room temperature. After cooling, two layers are observed with top layer identified as methyl ester and bottom layer as since it has more density. Then the top layer is washed with distilled water and drained out [26]. Finally, pongamia oil methyl ester (PME) is obtained as product and is used in the present study. Tests are conducted to analyze the composition and physical–chemical properties of biodiesel are presented Table 1. It is comprehended that the physicochemical properties of biodiesel differ from that of conventional diesel, which could affect the diesel engine performance and emission characteristics.

Particulars	Values
Purity	99%
Average particle size	10-25nm
Color	White
Crystallographic structure	Spherical
Atomic weight	79.8658 gm/mol
Melting range	1830 ^{0}C – 1850 ^{0}C
Boiling range	2500 ^{0}C – 3500 ^{0}C
Density at 20^{0}C	3940 kg/m^{3}

Table-1: Properties of Pongamia biodiesel

2.2 Nanoparticle

Nanoparticles typically measure 1 to 100 nm in diameter. This property of the material changes as the size of the particle changes. In this research work Titanium oxide is taken as additive for biodiesel for experimentation. The chemicals used for synthesis are Zinc acetate 2.1 gram in 100ml, Ammonium carbonate 0.96 gram in 100ml, Polyethylene glycol (5%) 5g in100ml. The titanium tetrachloride ($TiCl_4$) was used starting material in the synthesis. A 50 ml of $TiCl_4$ was slowly added to the200 ml in the ice cool bath. The beaker was taken from the ice bath to room temperature. The beaker was kept in magnetic stirrer to make a homogeneous solution for 30 minutes. Bath temperature was maintained at a temperature to 150^{o}C and kept in the same temperature till the process of nanoparticle was completed. In another vessel 26 gram of urea was dissolved in 250ml of distilled water. From the vessel 150 ml of urea solution was added to the beaker under constant stirring, drop by drop touching the walls of the beaker. The solution turned into white colloid without any precipitation. After the complete reaction, the solution was allowed to settle and the solution was washed with distilled water for 5 minutes.

Table- 2: Titanium oxide nanoparticle properties

Property	Unit	Value
Acid number	mg of KOH/g	1.53
Ash	% by mass	0.085
Pour point	^{o}C	-1
Distillation (a) At 350 ^{o}C	^{o}C	31
(b) At 370 ^{o}C	^{o}C	46
Flash point, ^{o}C	^{o}C	175
Kinematic viscosity at 40 ^{o}C	CSt	10.29
Moisture content	% by volume	0.4
Density at 15 ^{o}C	kg/m3	912
Lower heating value	kJ/kg	34220

3. EXPERIMENTAL SETUP

Experiments were conducted on a four-stroke single cylinder direct-injection water-cooled Diesel engine, specifications of engine test rig are listed in Table 3. Diesel engine is coupled with Eddy Current dynamometer for loading and five-gas analyzer was used to measure the emission characteristics such as unburned hydrocarbon(UHC),carbon monoxide(CO), oxides of nitrogen(NO_X),carbon dioxide(CO_2) and oxygen(O_2) values from the exhaust gas. Test was carried out with constant Injection pressure of200bar at a rated speed of 1500rpm with constant compression ratio 17.5, for the mixture of Diesel, biodiesel and 150ppm, 250ppm and 350ppm Titanium oxide nanoparticle as additives. From various literatures it was observed that 20% (B20) of biodiesel gives better performance [26]. So, in this experimental study, the same proportion of biodiesel blends with the nanoparticles

had been used and experimental tests are carried out as per ASTM standard test procedures.

Fig-1: Four stroke single cylinder diesel engine.

Table- 3: Engine specification

Engine Parameters	Specification
Engine	Four stroke single cylinder
Make	Kirloskar
Number of cylinders	Single Cylinder
Horse power	3.75 kw
Speed	1500rpm
Bore	80mm
Stroke length	110mm
Compression ratio	17.5 : 1
Starting	Manual
Working cycle	Four stroke
Injection pressure	200 bar
Method of cooling	Water cooled
Method of ignition	Compression ignition
Dynamometer	Eddy Current dynamometer

3.1 Preparation of blends

Magnetic stirrer technique was followed for dispersion of Titanium oxide nanoparticles with the base fuel. A known quantity of nanoparticles were weighed (150ppm, 250ppm and 350ppm) then poured in to B20 blend of Pongamia biodiesel and properties of Diesel, D+B20, D+B20+N150ppm, D+B20+N250ppm and D+B20+N350ppm are measured based on ASTM standard and formulated in table 4.it shows that by addition of nanoparticles calorific value of blends increased and flash point, fire point of fuel are decreased.

Table-4: Properties of Diesel and Biodiesel blends

Fuel	Diesel	D+B20	D+B20+N150ppm	D+B20+N250ppm	D+B20+N350ppm
Kinematic Viscosity(Cst)	4	5.2	5.21	5.23	5.26
Calorific Value (MJ/kg)	42.3	39.15	41.69	41.86	42.10
Flash Point (°C)	54	68	65	62	58
Fire Point (°C)	65	126	95	78	72

4. RESULTS AND DISCUSSION

The engine tests were conducted on a single cylinder diesel engine using different fuel blends in order to enhance engine performance and emission characteristics and results were compared with neat diesel.

4.1 Brake Thermal Efficiency (BTE)

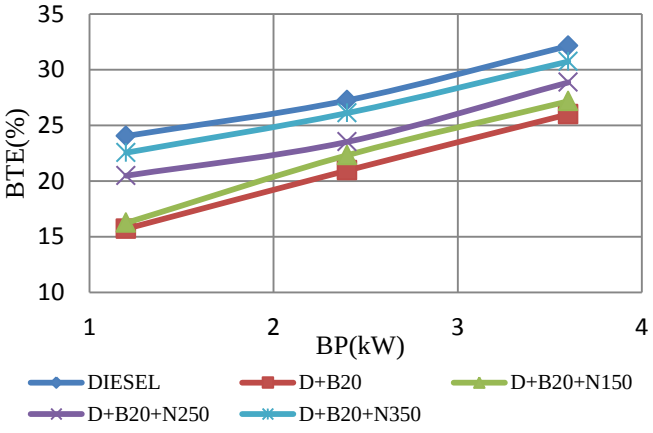

Chart-1: Variation of Brake thermal efficiency with brake power

The variation of brake thermal efficiency with brake power for different fuel blends is shown in Figure 2.the brake thermal efficiency of engine was enhanced with increase in Titanium oxide Nanoparticles quantity in the blends of all loads, D+B20+N350ppm shows better performance compare to other blends, Titanium nanoparticles promote complete combustion this leads to high flame temperature and efficiency, D+B20+N350ppm blend gives maximum efficiency of 30.10% when diesel gives 32.14%.

4.2 Brake Specific Fuel Consumption

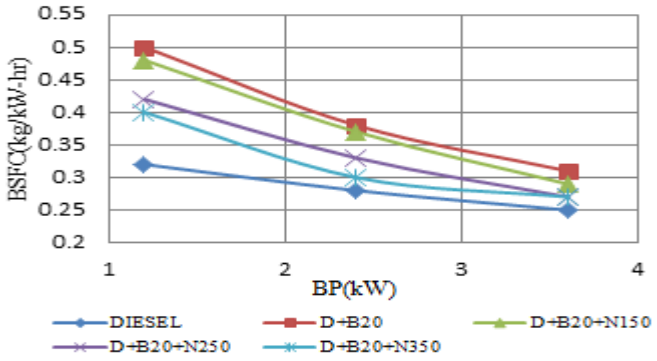

Chart -2: Variation of Brake specific fuel consumption with brake power

The variation of Brake specific fuel consumption (BSFC) with brake power for various blends is shown in Figure 3.Brake specific fuel consumption decreases with increase in engine load, from the comparison it is evident that D+B20 blend consumes34.6% more fuel then diesel due to their lower calorific value. Among these blends B20 N350ppm consumes lesser fuel compare to other blends and 7.4% more fuel consumed compare to diesel

4.3 Carbon Monoxide emissions

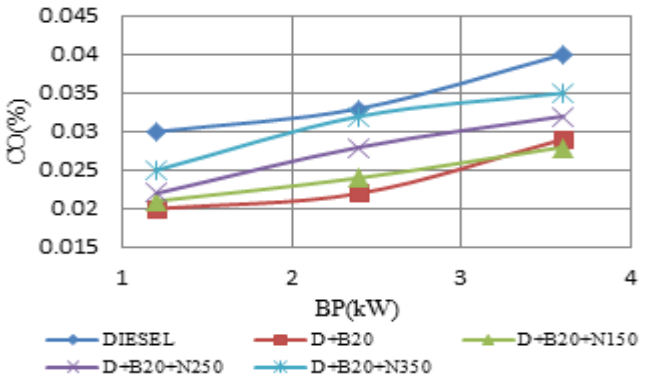

Chart -3: Variation of Carbon monoxide emission with brake power

The variation of carbon monoxide (CO) emissions with brake power for different fuel blends are illustrated in Figure 4. The carbon monoxide emission decreases with addition of biodiesel and Titanium oxide nanoparticles compared with neat diesel. Biodiesel blend shows lowest carbon monoxide emission about 0.02% and marginal decrease in carbon monoxide emission compare to diesel in all the blends compare to neat diesel due to higher oxygen content in biodiesel and catalytic impact of nanoparticles.

4.4 Hydrocarbon emissions

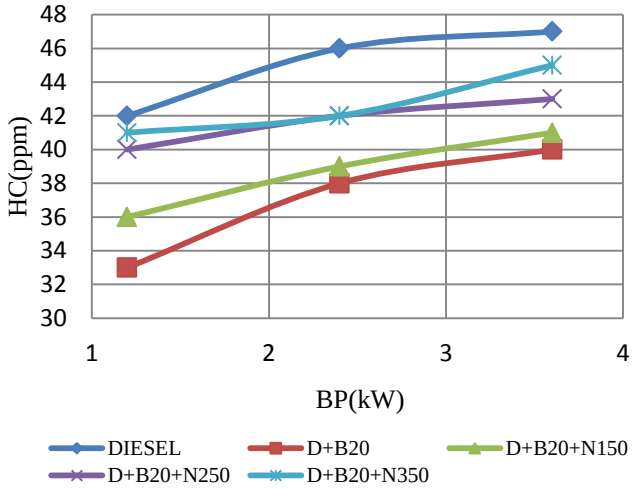

Chart -4: Variation of Hydrocarbon emission with brake power

The variation of hydrocarbon (HC) emission with brake power is shown in Figure 5. The addition of biodiesel and Titanium oxide decreases the hydrocarbon emission when comparing with neat diesel and lowest hydrocarbon emission is in biodiesel blend and marginal decrease in biodiesel with Titanium oxide nanoparticles blend. Due to high oxygen content in biodiesel and nanoparticles additives promotes complete combustion. Biodiesel produces 4.2% less hydrocarbon emission in full load compare to diesel.

4.5 Oxides of Nitrogen emissions

The variation of Nitrogen oxide with Brake power is shown in Figure 7. Biodiesel and Titanium oxide nanoparticles blend produce17.75% higher emission compare to neat diesel because of rich oxygen content in biodiesel and catalytic properties of nanoparticles generate high combustion temperature which oxidizes more nitrogen in to oxides.

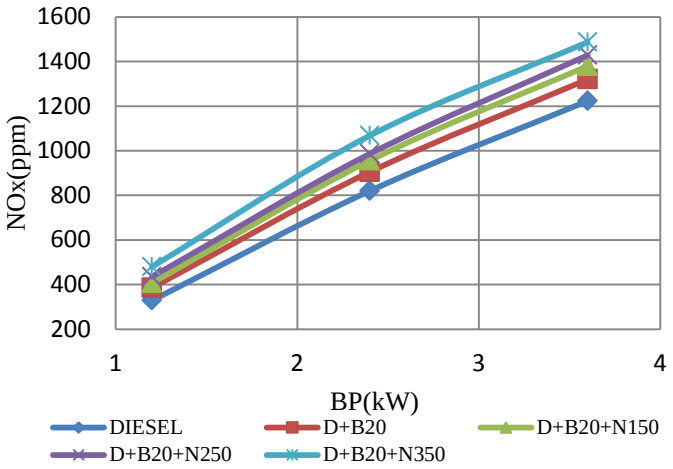

Chart -5: Variation of Nitrogen oxide emission with brake power

5. CONCLUSIONS

The performance and emission characteristics of a CI engine with Diesel Biodiesel blends and Titanium oxide nanoparticles as additive were investigated. The following conclusions were made from the experimental results.

- The Brake thermal efficiency of engine increases with increase in the nanoparticle quantity in blends, 15% improvement in BTE is observed in nanoparticle blends compare to B20 and 4.4% less than Diesel fuel.
- Break Specific Fuel consumption decreses with increase in nanoparticle quantity in blends. 20% of fuel consumption increased in B20 blend and7.4 % in D+B20+N350ppm.
- In the exhaust emissions25% to30% reduction in CO and 10% to15% reduction in HC are observed due to better combustion.
- NO_x emission increased by 7% in biodiesel blends due to higher oxygen content and increase combustion temperature.

Based on experimental result it has been concluded that Titanium oxide nanoparticles enhances the engine performance and considerable reduction in exhaust emissionsof diesel engine.

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