International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 4, Issue 6, June-2018

PERFORMANCE AND EMISSION CHARACTERISTICS OF TITANIUM DIOXIDE (TiO_2) NANOPARTICLE ADDITIVE IN DIESEL AND BIO DIESEL BLENDS ON THE CI ENGINE

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Abstract— In this paper an attempt is made to use titanium dioxide nanoparticles as fuel additive in a C.I. Engine. Dispersion of nanoparticles in B20 methyl ester of linseed oil is carried out using a probe sonicator. The physiochemical properties are characterized. The fuel samples are then tested in C.I. Engine test rig. Results reveal that use of titanium dioxide nanoparticles as fuel additives lead to enhanced performance and emission characteristics in comparison to plain fuel and biodiesel sample. The brake thermal efficiency of the engine is improved by 2.2% with the usage of TiO_2 nanoparticles in B20 blend, when compared with fuel sample without nano additive. A 6% reduction in BSFC value is observed for TiO2 nano fuel B20+50ppm and B20+100ppm in comparison to plain oil. It is observed that the blend B20 with TiO_2 nanoparticles result in an average 16% lesser smoke emission compared to plain B20.

Keywords— Nanoparticle, BSFC, Titanium Dioxide, linseed oil, B20+50ppm, B20+100ppm

INTRODUCTION

The compression ignition engines are widely used due to its reliable operation and economy. As the petroleum reserves are depleting at a faster rate due to the growth of population and the subsequent energy utilization, an urgent need for search for a renewable alternative fuel arise. Also the threat of global warming and the stringent government regulation made the engine manufacturers and the consumers to follow the emission norms to save the environment from pollution. Among the many alternative fuels, biodiesel (vegetable methyl esters) is considered as a most desirable fuel extender and fuel additive due to its high oxygen content and renewable in nature. Biodiesel is a renewable and eco- friendly alternative diesel fuel for diesel engine. Biodiesel has higher viscosity, density, pour point, flash point and cetane number than diesel fuel. Biodiesel is an oxygenated fuel which contains 10–15% oxygen by weight percent. Also it can be said a Sulphur free fuel. These facts lead biodiesel to total combustion and less exhaust emissions than diesel fuel. Furthermore also the energy content or net calorific value of biodiesel is about 12% less than that of diesel fuel on a mass basis. Using optimized blend of biodiesel and diesel can help reduce some significant percentage of the world's dependence on fossil fuels without modification of CI Engine, and it also has important environmental benefits. For example using optimized blend of biodiesel and diesel instead of the conventional diesel fuel significantly reduces the exhaust emissions particulate matter (PM), carbon monoxide (CO), sulfur oxides (SOx), and unburned hydrocarbons (HC). Moreover additives are an essential part of today's fuels. Together with carefully formulated base fuel composition, they contribute to efficiency reliability and long life of an engine. They can have surprisingly large effects even when used in parts per million (PPM) range. With use of fuel additives in the blend of biodiesel and diesel fuelled in CI Engine which furthers more improve performance, combustion, and diminish emission characteristics and also improved fuel properties which enhance the combustion characteristics.

Naresh Kumar Gurusala et al. reported that Aluminium oxide (Al2O3) nanoparticles were used as fuel born catalyst in order to enhance the combustion characteristics and reduce the harmful emissions. The engine test results showed less improvement in brake thermal efficiency and smoke reduction of 52.8 % was observed in B40 fuel blend with 50 ppm alumina nanoparticles under full load conditions. Nanoparticles have been used as fuel additive in recent researches. They tend to improve the properties of the base fuel which tends to the better combustion of fuel and reduction in emissions . S. Karthikeyan observed that Cerium oxide nanoadditive in the fuel for C.I.Engine increased the heat release rate and thermal efficiency and also reduced the fuel consumption.

According to the micro-explosion theory, the turbulence between air and fuel mixture increases resulting in better atomisation of fuel. Ferrofluid when used in biodiesel have been found to enhance the combustion characteristics and reduce NOx The impact of aluminium nanofluid in petroleum diesel was studied by Kao et al. [11]. Here the efficiency was found to be better and BSFC, NOx, smoke has decreased. Copper Oxide (CuO) nano particles (50 ppm) in B20 blend of Mahua methyl ester reduced HC, CO and smoke emissions up to 5.33%, 33% and 12.5% compared with biodiesel blend .It was reported that adding 40–60nm of aluminium nanofluid to diesel, a reduction of 4.1% in smoke emissions and 6.2% in NOx emissions were found. Zinc Oxide nanoparticles when used with anola methyl ester have found to be giving 2.79% better efficiency than the anola methyl ester without nanoparticles. Also NOx emissions have been found 3.82% lesser and smoke 7.2% lesser when zinc oxide nanoparticles are used. M. B. Shafii,1 F. Daneshvar conducted an experimental investigation to study the performance of nano particles in the application to the single cylinder water-cooled direct injection diesel engine developing a power output of 3.7 kW at the rated speed of 1500 rpm at various output along with the basis for comparison with the blending, biodiesel, and dual fuel operation techniques. They found that ferrofluid resulted in slightly incresed thermal efficiency as compared to diesel. CO emission was higher with jatropha oil as compared to diesel. The smoke level with ferrofluid was decreased among that of diesel.

Addition of nano additives in Diesel fuel improves the property of fuel which is helpful for decreasing the emission. If the additives are Nano sized the reaction will be more efficient due to high surface to volume ratio and high surface energy. Lot of studies carried out in the area of single nanoparticle in Diesel fuel, Bio Diesel and Diesel-Bio diesel blend. In this work the effect of Nano additives such as TiO2, composite of bio diesel and additive on diesel fuel properties are investigated. Nanoparticles of size range 10-50 nanometres are used to prepare the Nano fuel with diesel as the base fuel. Nano fuels are prepared for the experiments using an ultrasonic vibrator. The physicochemical properties of the base fuel and the modified fuel are measured accurately using ASTM standard test methods. The studies are extended with different dosing levels of the Nano particles that are B20+TiO2 50ppm and B20+TiO2 100ppm and compared the performance and emission characteristics.

II BIODIESEL PREPARATION

a)DETERMINATION OF FFA CONTENTS IN THE LINSEED OIL

The FFA in the Lin seed oil was determined until the titration process. The measure KOH filled were about 5.61grams were dissolved in the 1000ml of distilled water to prepare the 0.1 Normality KOH solution. A measured weight of PO was taken in the conical flask which is heated about 60°C of temperature.

The phenolphthalein indicator solution were added about 3 to 5 drops to the oil which indicate the coolant of the solution. The alcohol (methanol) about 10ml was added to PO and stirred to prepare homogenous solution. The 0.1 Normality solution was filled in the burette and reacted the in trail reading slowly release the 0.1 N solutions in to the conical flask and stirrer the solution slowly. After some time solution was changed to pink color permanently. At this time record the burette readings which will give quantity of KOH solution used. This set up for titration process as shown in Figure 3.1. The Acid value & FFA in the palm oil was measured using the equation 3.1 & 3.2. The FFA value in the palm oil is recorded as 0.9% (<1% of FFA). So, it is easy to convert linseed oil into biodiesel using transesterifiction process.

$$\text{Acid Value} = \frac{56.4 \times T \times N}{\text{wt.of the oil}} \qquad (1)$$

Where T= volume of KOH solution was consumed (ml)

N= Normality of the solution

$$\%FFA = \frac{\text{Acid Value } 56.4 \times T \times N}{1.99} \qquad (2)$$

Where T= volume of KOH solution was consumed (ml)

N= Normality of solution

b)TRANSESTERIFICTION REACTION

The process parameters studied here are methanol-to-oil ratio 1:3, 1:6 and 1:9, Reaction time was from 60 to 120 minute, Temperature at a constant 60°C, alkaline catalyst was 0.5, 1.0 and 1.5 wt. % of KOH. The typical reaction was carried out conducted in a three-neck round bottom flask (500ml) equipped with a reflux condenser, temperature indicator, and mechanical stirrer. The alkali catalyst of potassium hydroxide had been used to carry the transesterification process with methanol. This work carried by parameters of biodiesel yield finding the optimal values of reaction time of 60 minute, reaction temperature of 60°C, speed of 600 rpm, molar ratio of methanol to oil ratio of 3:1 and 1% wt. KOH as catalyst to produce biodiesel at a 60°C. The final yield for methyl ester was achieved at 90% in 1hrs. The reaction product was then poured into a separation funnel and ultimately, in this process, the two layers were formed, where by the upper layer was the biodiesel and lower layer was the glycerine would settle down at the bottom of the separation funnel.

CH2−COO R1   R1COOCH3   CH2OH
| KOH | |
CH COOR2   + 3 CH3OH ⟶   R2COOCH3 + CHOH
| | |
CH2 COOR3   R3COOCH3   CH2OH

Triglyceride + methanol ⟶ biodiesel + glycerol

1 oil + 3 methanol   3 methyl esters + 1 glycerine

c)PREPARATION OF NANO FUEL

$$xppm = \frac{mass\ of\ nanoparticle}{Massof\ fuel} X10^6$$

By using this equation for particular mass of Nano particles are taken corresponds to particular ppms by using an electronic weighing balance. In an electronic vibrating machine the proper blend is prepared within 20 minutes of time, in that time we can see that the transparencies of the pure diesel get reduced. Also another Nano fuel is prepared by blending the base fuel with TiO2 nanoparticles of size 20nm.Property testing is carried out at 50ppm and 100ppm

III BLENDING OF DIESEL, BIODIESEL AND ADDITIVE

1. MAGNETIC STIRRER:

Electro Magnetic stirrer is used to mix components to get homogeneous mixtures (or) the function of a stirrer is to agitate liquids for speeding up reactions or improving mixtures. Magnetic stirrers minimize the risk of contamination since only inert magnetic bar rotates inside, and it can be removed, cleaned easily. Reproducible mixing or mixing over long time scales is possible through it. Diesel and linseed bio-diesel are mixed according to the required ratio of blending and exposed to stirring for at least 45 minutes at 1540C, after that by adding the nano particles which measured to 50ppm, and 100ppm to the blend and exploit it to the sonication using ultrasonicator.

2. ULTRASONICATOR:

SPECIFICATIONS:

Sonics& Materials make

Power--- 130W

Volts --- 230V, Ten hours timer.

Fig. 1 Ultra Sonicator

The TiO2 Nano powder of 50ppm and 100ppm mass fractions are added to blends which already prepared and is exploited with ultrasonicator at a frequency of 40 KHz and 120 W for 60 min due to sound energy of sonicator nano particles get agitated and dispersed in blend, from above fig we can observe that the color change of blend into dirt white, it is observed for 48 hrs. does not produce any precipitate of nanoparticles. Thus the diesel and biodiesel blend with TiO2 nanoparticles as additive is used to test on diesel engine.

PROPERTIES	DIESEL	LINSEED OIL	B20	B20+50PPM	B20+100PPM
Density (Kg/M^3)	850	921	860	870	875
Kinematic Viscosity @ 45 ^{0}C (c St)	2.981	22.12	3.264	3.427	3.435
Calorific Values (KJ/Kg)	43000	37225	41175	41243	41305
Fire Point (^{0}C)	60	205	72	76	80
Flash Point (^{0}C)	52	197	76	79	89

Table 1: Properties of Diesel and Linseed oil with nano additives

Table.2 shows the variation of the flash & Fire point of the diesel as a function of the dosing level as illustrated, the diesel shows a decreasing trend for the flash & Fire point with the dosing level.

III EXPERIMENTAL SETUP

1.ENGINE:

In the test setup a constant speed, single cylinder four strokes, water cooled, high speed diesel engine as shown in figure.1.and a rope brake dynamometer is used to measure the power of the engine. Adjacent to the engine there is a measurement board which contains read outs for temperature and a clear graduate tube i.e. fuel metering system which is used to measure the amount of fuel consumed per unit time. The temperature measurements can be made through the usage of thermocouples placed at appropriate places inside the engine. The rope brake dynamometer is used to measure the power of the engine. The load is varied and readings are taken accordingly. The experiments are conducted for different loads i.e. 0,500,1000,1500,2000W respectively.

Fig 2 Set up of Engine with test rig

The experimental set up consists of KIRLOSKAR engine, DC alternator with resistance heaters, Rota meter, digital RPM indicator fuel tank along with immersion heater, thermocouples and manometer.

Model	AV1
Make	KIRLOSKAR
Engine type	Single cylinder, 4 stroke, Water cooled CI engine
Bore	80 mm
Stroke	110 mm
Speed	1500 rpm
Rated power	5hp

Table 2 Specifications of Engine

2.EXHAUST GAS ANALYSER

INDUS model PEA205 is a 5-gas analyser meant for monitoring CO, CO2, HC, O2 and NO in automotive exhaust. It meets OIML Class-I specifications. CO, CO2 and HC (Hydrocarbon residue) are measured by NDIR technology and O2 and NO by electrochemical sensors. It is also supplied as a 4-gas analyser which can be upgraded easily to 5-gas version by the addition of an NO sensor. It has many control features to prevent faulty measurements. A built-in dot matrix printer is provided to print out a hard copy of the results. It conforms to CMVR 115/116 and is certified by ARAI, Pune

Fig 3 Exhaust gas analyser

SPECIFICATIONS OF GAS ANALYSER

MODEL	PEA205
MAKE	INDUS dcienii c Private Limited
Gases Measured	Carbon monoxide, Carbon dioxide, Oxygen, Oxides of Nitrogen & Hydrocarbon
Principle	Non - Dispersive Infra - Red for CO, CO,& HC, Electrochemical sensor for O, & NO.
Range	CO: 0 to 15%, HC: 0 to 30000 ppm as hexane, O,: 0 to 25%, CO,: 0 to 20%, NO: 0 to 5000 ppm
Operating Temperature	0 to 45^0 C
Sample Handling System	S.S. probe, PU tubing with easily detachable connectors, water separator cum filter, disposable particulate fine filter
Keyboard	Membrane keypad with 16 keys
Accuracy	CO: T 0.06%, CO,: + 0.5%, HC: + 12 ppm, O,: + 0.1%

Table 3 Specifications of 5Gas analyser

EXPERIMENTAL PROCEDURE

Experimental procedure was explained below.

1. The engine is started at no load condition and allowed to work for at least 10 minutes to stabilize.
2. The readings such as time taken for 10cc fuel consumption, ammeter & voltmeter readings etc. were taken as per the observation table.
3. The load on the engine was increased by 20% of FULL Load using the engine controls and the readings were taken as shown in the tables.
4. Step 3 was repeated for different loads from no load to full load.
5. After completion of test, the load on the engine is completely relieved and then the engine is stopped.
6. The above experiment is repeated for various blends on the engine. The experimental procedure is similar as foresaid. While starting the engine, the fuel tank is filled in required fuel proportions up to its capacity. The engine is allowed to run for 20 min, for steady state conditions, before load is performed.

IV Results and Discussions

A. ENGINE PERFORMANCE

I. Brake specific fuel consumption

The result for the variations in the brake specific fuel consumption (BSFC) with load is presented in the fig 4. Brake Specific Fuel Consumption (BSFC) is a measure of fuel consumed by the engine to produce unit power in unit time. BSFC reduces with the increase in load.

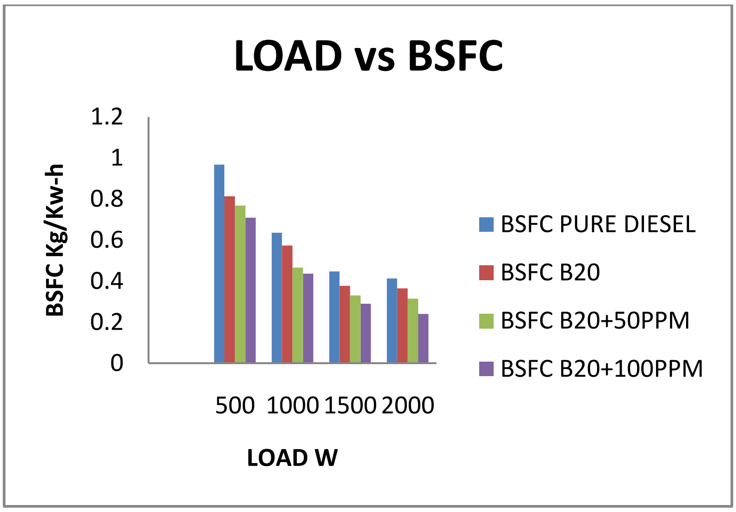

Fig 4 Variation of BSFC with respect to engine load at 1500 rpm.\

In the present work it is observed as shown in Figure 4, that the BSFC value is reduced when nanoparticles are used as fuel additives. The fuel sample of B20 with titanium dioxide nanoparticles shows 6% reduction in BSFC value compared to the BSFC value when B20 is used at all the loads.

According to experimental results, adding 50ppm of TiO_2 to B20 fuel decreased the BSFC relatively by 3.23–6.45%, adding 100ppm of TiO to B20 fuel decreased the BSFC relatively by 5.06–10.85%.

The decrease in BSFC can be due to the positive effects of nanoparticles on physical properties of fuel and also reduction of the ignition delay time, which lead to more complete combustion. In addition, it can be due to effects of nanoparticles on fuel propagation in the combustion chamber.

On the other hand, nanoparticles added to diesel fuel increase the mixture momentum and, consequently, the penetration depth in the cylinder. As a result, combustion is improved. This result is also in agreement with similar experiments done.

BRAKE THERMAL EFFICIENCY

Brake thermal efficiency is a measure of performance of the engine. As load increases the brake thermal efficiency of the engine increases. Among the fuel samples used apart from Diesel, the blend B20 with 100ppm TiO_2 nanoparticles gives better brake thermal efficiency. It is observed from the Figure 5, that there is an increase in brake thermal efficiency when nanoparticles are used as fuel additive. Compared to B20, there is 2.2% increase in brake thermal efficiency at higher load when Titanium dioxide nanoparticles are used. Figure 5, shows the variation of the brake thermal efficiency with load for diesel, B20 and B20 with nano fluid additive with different proportions.

The thermal efficiency obtained for diesel and B20 are 25.62.13%, 23.93% respectively at full load.

The decrease in thermal efficiency for B20 when compare to diesel is due to lower calorific value, higher viscosity and ineffective utilization of heat energy due to higher molecular weight of methyl ester. whereas for B20 with TiO_2 for 50ppm and 100ppm are 27.67% and 28.13% .

The increase in thermal efficiency when B20 is added with an additive of 50ppm and 100ppm when compare with B20 and diesel was due to sufficient oxygen content present in nano fluid. Due to this it forms homogeneous mixture and proper combustion takes place and leads to higher thermal efficiency.

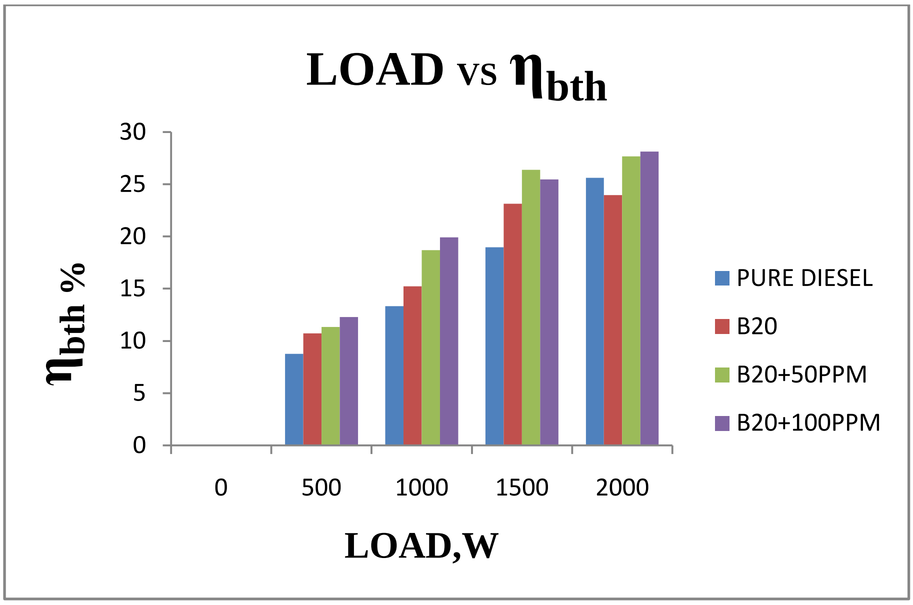

FIG 5 VARIATION OF BRAKE THERMAL EFFICIENCY WITH RESPECT TO ENGINE LOAD AT 1500 RPM.

B. ENGINE EXHAUST EMISSIONS

CARBON MONOXIDE EMISSION

Figure 6 shows the variation of carbon monoxide (CO) emissions with load for diesel, biodiesel blend with and without nano particle. The carbon monoxide emission increases with biodiesel blend than neat diesel fuel at part load. The CO emission is marginal up to the 75% of the load and then decreases rapidly with full load. The addition of titanium oxide further decreases the CO emission when comparing with neat diesel. The lowest CO emission is obtained for 50 ppm and 100ppm nano particle with B20 are 0.018%Vol and 0.017% Vol respectively, whereas for diesel it is 0.021%Vol at full load. The decrease in CO emission may be due to the activation energy of titanium oxide, which oxidizes the biodiesel, resulting in complete combustion.

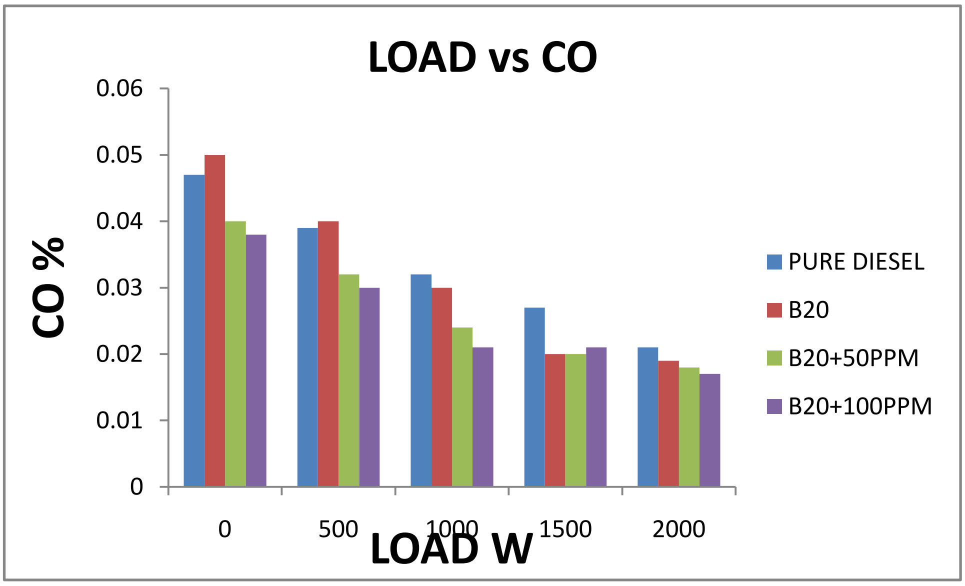

FIG 6 VAIRATION OF CARBON MONOXIDE WITH RESPECT TO ENGINE LOAD AT 1500 RPM.

The increase in CO at lower loads is due to rich mixture of fuel. A small amount of CO will come out of the exhaust even the mixture is lean because of non-equilibrium condition established when the products passed to exhaust.

UN BURNED HYDRO CARBONS (UBHC)

The amount of UHBC present in the exhaust as a function of load for all fuels is illustrated in Fig. 7. The main sources of these emissions in diesel engine are lean mixing, burning of lubricating oil and wall quenching. The HC emissions are reduced considerably due to the completion of combustion of the fuel with hot combustion chamber.

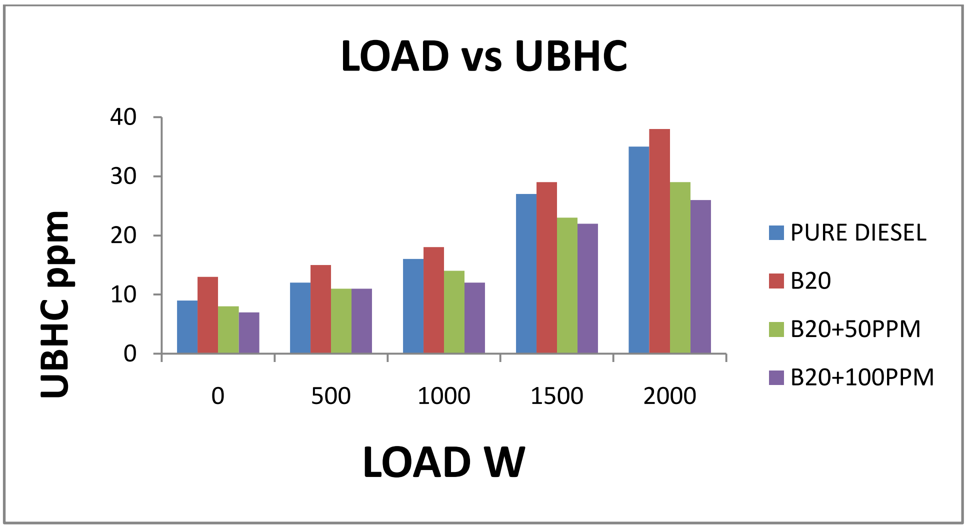

Fig7 : VAIRATION OF UBHC WITH RESPECT TO ENGINE LOAD AT 1500 RPM.

Emission of hydrocarbon in the exhaust is not desirable as it shows the inadequacy of the engine to burn the fuel, resulting in loss of power and efficiency. It is observed from Figure 3, that the UBHC emissions increase with the load. Comparing the two fuels samples with nanoparticles as additives, it is observed that the blend B20 with titanium dioxide nanoparticles has considerable lesser UBHC in the exhaust at higher loads. The reason for reduction in UBHC may be TiO2 nanoparticles acting as oxygen buffers resulting in better combustion. The increase in UHBC for bio diesel blend is due to the high viscosity of fuel, at wall bio diesel is mixed with lubricant the combustion is in complete.

NO_x EMISSIONS

NOx is an undesirable emission particularly in diesel engines. The formation of NOx highly depends on in-cylinder temperatures, oxygen concentration, and residence time for the reaction to take place and air surplus coefficient. High combustion temperatures breaks the strong triple bond of nitrogen molecules, disassociates into their atomic states and participate in a series of reactions with oxygen and generates thermal NOx

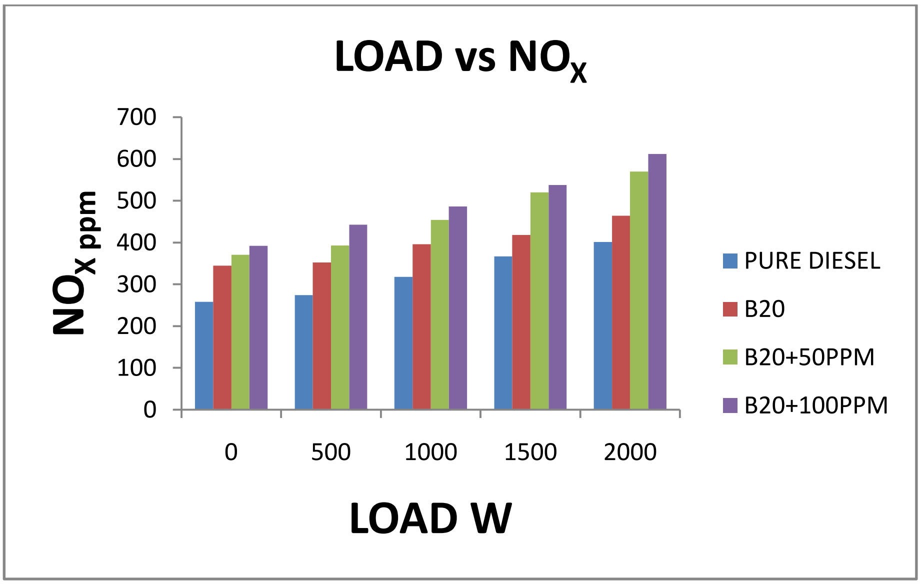

FIG8: VARIATIONS OF NOX WITH RESPECT TO ENGINE LOAD AT 1500 RPM.

The NOx emission increases with the increase in load. It is observed form the Figure 8 That the NOx emission is higher for Blend B20 at higher loads with titanium dioxide nanoparticles than the NOx emission of B20. This may be due to the better combustion occurring when TiO2 nanoparticles are present in the fuel sample.

CONCLUSIONS

The nanoparticle dispersions were obtained by sonication using a probe sonicator. The engine test revealed that by dispersing nanoparticles to the fuel, affects the performance and emission of the C.I.Engine. In the present work titanium dioxide nanoparticles were used as fuel additive. It is observed that the fuel sample with titanium dioxide nanoparticles shows better result.

There is 2.05% increase in brake thermal efficiency and 5.7% reduction in BSFC at most of the loads.

Among emissions, the unburnt hydrocarbons and smoke are found to be less in case of fuel sample with TiO2 nanoparticles.

NOx emissions are slightly higher at higher loads when TiO2 nanoparticles are used. Hence titanium dioxide nanoparticles with concentration of 100ppm in the B20 sample shows better performance and emission characteristics.

Co is slightly increasing at lower loads for B20 and decreasing at higher loads.B20+100ppm is giving better results when compared with pure diesel and B20.

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