INFLUENCE OF NANOPARTICLE WITH JATROPHA METHYL ESTER BLENDS IN A DIESEL ENGINE

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Titanium dioxide nanoparticle act as an additive added to Jatropha methyl ester blend at various proportions (50 and 100 ppm) was engaged in an unmodified diesel engine and its effect on engine emissions and performance characteristics have been investigated. The experimental results indicated that HC, CO, and smoke emission considerably decreases due to its catalytic activity and increased surface area to volume ratio, whereas NOx emissions are increasing slightly because of high peak pressure and heat liberation was occurs during combustion. In addition, the investigational results confirmed that the addition of 50 and 100 ppm of nanoparticle resulted in significant enhancement in thermal efficiency with lower consumption of fuel. Experimental results were established that the modified fuels reduce harmful emissions significantly from an unmodified diesel engine.

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1. Introduction

Biodiesels are the merely hopeful substitute fuel for diesel engines. Biodiesel obtained from natural resources like animal fat, vegetable oil, used cooking oil, etc. since it is sustainable [1,2]. Biodiesel obtained from Jatropha oil is indispensable since it is formed from non-edible oil source [3]. Employing the biodiesels in compression ignition engines can diminish the hydrocarbon, carbon monoxide, and smoke emissions. Nevertheless, NO_x emission will increase due to the oxygen presented in biodiesel thereby it causes the formation of NO_x emission in a diesel engine. Biodiesel properties like high viscosity, high pour point, high molecular weight, and lower volatility which are not desirable compared with neat diesel [4]. These shortcomings make poor vaporization and escort to incomplete combustion [5]. Thus, metal additives could achieve lower emissions and help to meet the emission norms. It is found that oxygenated additives like diethyl ester, dimethyl ester, methanol, ethanol, and butanol etc. reduces NO_x emissions and gives the stability of biodiesel [6]. The existing biodiesel properties could be altered by adding nanoparticles into the biodiesel blends. The metal additives such as aluminium oxide, zinc oxide, iron oxide, and titanium dioxide added to the biodiesel to improve fuel properties. The use of nano-additives perform as a catalyst which improves the combustion characteristics, shorter ignition delays, increases in energy density, and reduces the emissions [1]. Sundaram et al. [7] have reviewed on use of nano aluminium particles in combustion, it is reported that nanoparticles have a larger surface to volume ratio which leads to the quick oxidation thereby higher release of heat. Syed Aalam et al. [8] have done an investigation on CRDI diesel engine powered with biodiesel and aluminium oxide nanoparticle, they found there is a rise in NO_x emission slightly and substantial decrease in CO, HC, and smoke emissions.

Based on comprehensive assessment addressing the emission characteristics of different nano-additives with biodiesel fuels and its effect on a CI engine, It is observed that the extensive

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investigation on performance and emission characteristics with titanium dioxide (TiO_2) nanoparticles mixed Jatropha methyl ester (JME) has not been done. In this work, an effort has been attempted to investigate the possible effects of Jatropha methyl ester-titanium dioxide-diesel blends on performance and exhaust emissions characteristics in an unmodified diesel engine (naturally aspirated, constant speed, single cylinder) at different operating conditions and the outcome was compared with biodiesel without TiO_2 nanoparticle. This work analyzes the feasibility of utilizing JME with TiO_2 as fuel in unmodified diesel engine also it examines the differences in emission and performance characteristics for various proportions (50 and 100 ppm).

2. Materials and methods

2.1. Base fuel preparation (JME)

The alteration of biodiesel from Jatropha oil was done by the transesterification method (alkaline catalyzed) [9]. Potassium hydroxide act as a base catalyst and methanol were mixed with Jatropha oil then the mixture was stirred for 90 minutes for 60^oC. The maximum biodiesel yield obtained at optimum conditions are as follows: alcohol to oil (molar ratio): 6:1, concentration (catalyst): 1%, time for the reaction: 90 minutes, and reaction temperature: 60^oC. The JME biodiesel was cleansed with hot water to get rid of residual catalyst and alcohol and again it was heated up to 80^oC in order to get rid of the moisture.

2.2. Modified fuel Preparation (B50A50 & B50A100)

In order to improve TiO_2 nanoparticle stability, the surfactant (certyl trimethyl ammonium bromide) makes conceal on the face of the TiO_2. The Ultrasonicator is used for diffusion of TiO_2 with the biodiesel. TiO_2 and surfactant (certyl trimethyl ammonium bromide) were weighed and mixed into the solvent (ethanol). The stable nanoparticle was unified with the biodiesel blend. It is done by use of an ultrasonicator about 45 minutes for TiO_2 of 50 ppm and 100 ppm. The frequency of ultrasonicator is 24 kHz. This mixing is done for better diffusion of particles and also makes homogeneous blends. The prepared test fuels are referred as B50 (50% diesel, and 50% JME), B50A50 (50% diesel, 50% JME, and 50 ppm TiO_2), and B50A100 (50% diesel, 50% JME, and 100 ppm TiO_2). Table 1 shows the measured (ASTM standard methods) properties of biodiesel blends.

Table 1. Properties of Diesel, JME, Diesel- JME blend, and Diesel-JME-TiO_2 blend.

Properties	Diesel	JME	B50	B50A50	B50A100	Method
Kinematic viscosity at 35^oC (mm^2/s)	3.88	4.91	4.44	4.52	4.55	ASTM D445
Density at 20^oC (kg/m^3)	845	864	856	858	860	ASTM D4052
Calorific value (kJ/kg)	42500	39350	41400	41530	41580	ASTM D240
Cetane index	47	53	50	52	53	ASTM D976
Oxygen (%)	Nil	0.036	0.040	0.044	0.044	-

3. Engine testing experimental setup

Table 2 shows the technical details of the experimental engine setup. A naturally aspirated, constant speed, direct injection diesel engine operated in this study shown in Figure 1. The dynamometer (eddy current) was affianced to vary the load. Data acquisition system employed for various measurements. The air in-flow to the inlet was measured using manometer (U-tube). The fuel rate was measured by using a stopwatch. The calibrated five gas analyzer (AVL Digas 444) was employed to measure the exhaust emissions. Smoke opacity meter (smoke meter AVL 437) employed to measure smoke emissions.

Table 2. Technical specification of engine setup.

Parameters	Specification
Made	Kirloskar
No. of Stroke	4
No. of cylinder	1
Type of cooling	Water cooled
Type	Vertical, direct injection, diesel engine
Maximum power	3.7 kW
Maximum speed	1500 rpm
Bore diameter	80 mm
Stroke length	110 mm
Compression ratio	16.5:1
Injection pressure	210 bar
Injection timing	23^{o} BTDC
Load type	Eddy current dynamometer

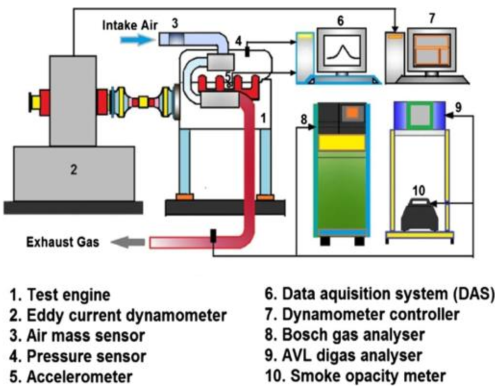

Fig. 1. Experimental setup layout

4. Results and discussion

The different engine tests were carried out on an unmodified diesel engine (constant speed, naturally aspirated, water cooled, single cylinder, direct injection) operated at different operating conditions. Emission and performance characteristics on biodiesel blends by appending TiO_2 nanoparticle at 50 and 100 ppm are discussed and results were compared with a biodiesel blend.

4.1. Carbon monoxide (CO) emission

The changes in carbon monoxide emissions with respect to brake power (BP) for diesel, B50, B50A50, and B50A100 are shown in Figure 2. From the figure, it is understood that there is a noteworthy decrease in CO emissions of JME biodiesel blends with TiO_2 nanoparticles than compared with B50. The addition of nanoparticles increases reactions at earliest, which prompts shorten ignition delay. Moreover, the suitable mixture of air-fuel ratio and improved fuel property fetch to complete combustion, in turn, which gives a noteworthy reduction in CO emission contrast with fuel without TiO_2 [10,11]. This reduction of CO emission can be endorsed due to more oxygen in biodiesel blend and the catalytic reaction of TiO_2 nanoparticles which improves the combustion efficiency. The highest percentage of CO reduction is achieved by appending 100ppm of TiO_2 in JME biodiesel blend. CO emissions at maximum brake power for a diesel, B50, B50A50, and B50A100 were 0.165, 0.095, 0.08, and 0.073 by percentage of volume, respectively.

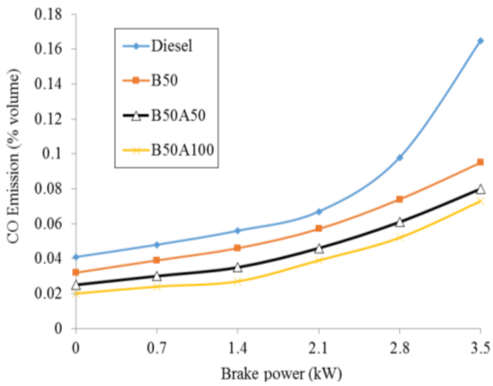

Fig. 2. Variation of CO emissions for tested fuels with different load conditions.

4.2. Hydrocarbon (HC) emission

The changes in hydrocarbon (HC) emissions with brake power (BP) for neat diesel, B50, B50A50, and B50A100 are shown in Figure 3. From the figure, it is understood that there is a noteworthy decline in HC emissions from JME biodiesel blends with TiO_2 nanoparticles than compared with B50. The reason for HC emission is owing to non-uniformity of the fuel-air mixture, aggravated by the short of oxygen during combustion [12]. HC emission is noticeably reduced when TiO_2 nanoparticles added to JME biodiesel blends. The addition of nanoparticles doped with biodiesel blends performs as catalyst accelerate the flame spread in the combustion chamber, which diminishes the activation of carbon and proceeds supplementary for comprehensive combustion. The inclusion of TiO_2 nanoparticles with JME biodiesel blends reduces HC emissions compared with biodiesel blend, this is because of the oxygen molecule and high cetane number [13,5]. HC emissions at maximum brake power for a diesel, B50, B50A50, and B50A100 were 55, 46, 38, and 36 ppm, respectively.

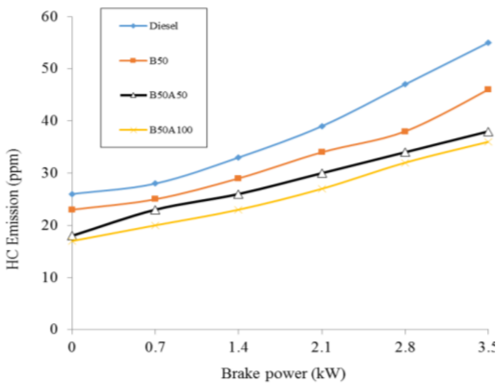

Fig. 3. Variation of HC emissions for tested fuels with different load conditions.

4.3. Nitrogen oxides (NOx) emission

The changes in nitrogen oxides (NO_x) emissions with brake power for a diesel, B50, B50A50, and B50A100 are shown in Figure 4. NO_x formation is a complex process which relies on many variables like peak temperature, heat content, oxygen content, engine design features, time, turbulence, and engine working conditions. It is evident that NO_x progressively increases the percentage of TiO_2 nanoparticles. Higher NO_x emissions in the JME biodiesel fuelled engine due to higher oxygen present in biodiesel. This exceedingly oxygenated fuel gives enhanced burning and also offers a high heat release rate which causes NO_x emission. Many researchers found similar investigational findings [14,15]. NO_x emissions were increased for the inclusion of TiO_2 nanoparticles with JME biodiesel blends compared with a B50. This is due to the higher calorific value and peak pressure during the combustion process. NO_x emissions at maximum brake power for a diesel, B50, B50A50, and B50A100 were 1070, 1200, 1290, and 1330 ppm, respectively.

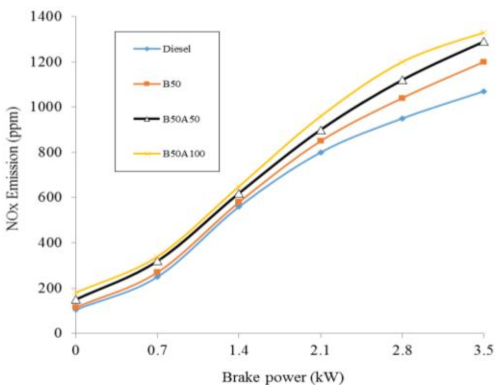

Fig. 4. Variation of NO_x emissions for tested fuels with different load conditions.

4.4. Smoke emissions

The changes in smoke emissions with brake power (BP) for diesel, B50, B50A50, and B50A100 are shown in Fig. 5. It is observed that smoke emissions reduced significantly with the addition of TiO_2 nanoparticles in JME biodiesel when compared with B50. Oxygen presents in the biodiesel, which persuades the decrease in smoke emissions due to improved combustion and also TiO_2 nanoparticle to act as a catalyst and enhances oxidation and consequently reduces smoke emissions at all brake power. Maximum reduction of smoke obtained from 100ppm of TiO_2, this is because of shorter ignition delay period and better ignition characteristics [16,17]. Smoke emissions at maximum brake power for a diesel, B50, B50A50, and B50A100 were 70, 64, 53, and 47 HSU, respectively.

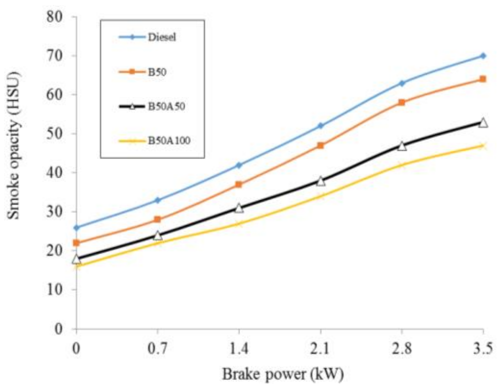

Fig. 5. Variation of smoke opacity for tested fuels with different load conditions.

4.5. Brake thermal efficiency (BTE)

The changes in brake thermal efficiency with respect to brake power for diesel, B50, B50A50, and B50A100 are revealed in Fig. 6. The decrease in BTE was observed for biodiesel under entire load operation owing to lower calorific value when compared to diesel [18]. However, the inclusion of TiO_2 nanoparticles has compensated the loss caused due to B50. The addition of 50 and 100 ppm of nanoparticles into B50 enhances the BTE up to 0.9 % at full load. The increase in thermal conductivity of B50A50 and B50A100 leads to increase the heat transfer rate during the delay period and hence shortens the delay period and initiates the combustion early. The highest percentage increase in BTE is achieved by appending 100 ppm of TiO_2 in B50. BTE at maximum brake power for diesel, B50, B50A50, and B50A100 were 29, 26, 26.3, and 26.9% respectively.

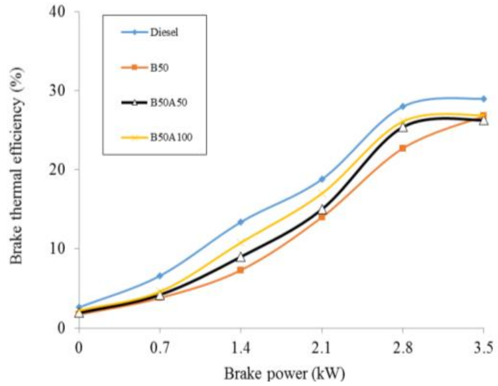

Fig. 6. Variation of BTE for tested fuels with different load conditions.

4.6. Brake specific fuel consumption (BSFC)

The changes of BSFC with respect to brake power for diesel, B50, B50A50, and B50A100 are shown in Fig. 7. The drop in BSFC was observed for biodiesel under all brake power owing to higher viscosity when compared to diesel [18]. However, the inclusion of TiO_2 nanoparticles has made a positive impact on BSFC. This could be endorsed to the enhanced surface area to volume ratio caused by the catalytic effect of TiO_2 nanoparticles [16,17]. By adding 50 and 100 ppm of nanoparticles into B50 plunge the BSFC up to 0.03 kg/kW-hr at full load. The TiO_2 nanoparticles are capable of oxidizing the carbon deposits within the cylinder which leads to a reduction of BSFC. BSFC at maximum brake power for diesel, B50, B50A50, and B50A100 were 0.17, 0.21, 0.2 and 0.18 kg/kW-hr respectively.

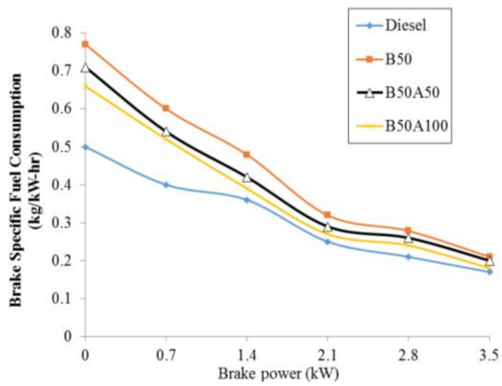

Fig. 7. Variation of BSFC for tested fuels with different load conditions.

5. Conclusion

Emission and performance characteristics on JME biodiesel blends by appending TiO_2 nanoparticle at 50 and 100 ppm are discussed and results were compared with a biodiesel blend. The following are the major effects of this study:

- JME biodiesel could be fuelled in a diesel engine as like any other biodiesel without any significant modifications.
- CO, HC, and smoke emissions reduce significantly at all engine working conditions and it follows the pattern of B50A100< B50A50< B50. This is because of catalytic activity and better surface area to volume ratio.

- NOx emission increases slightly at all engine working conditions and it follows the pattern of B50A100>B50A50>B50. The catalytic TiO2 nanoparticles reacted with oxygenated biodiesel engenders peak temperature, which oxidizes with nitrogen in due course encourages a higher rate of NOx formation.
- The inclusion of 50 and 100 ppm of TiO2 nanoparticles enhances the efficiency of B50 up to 0.9% and minimizes the consumption of fuel by 0.03 kg/kW-hr comparing to B50.

It has been summarized that TiO_2 nanoparticles are capable to reduce harmful emissions from the diesel engine. Furthermore, it is obviously implicit that the TiO_2 nanoparticles could be the hopeful additive for biodiesel.

Nomenclature

TiO_2	:	Titanium dioxide
JME	:	Jatropha methyl ester
B50	:	50% diesel, and 50% JME
B50A50	:	50% diesel, 50% JME, and 50 ppm TiO_2
B50A100	:	50% diesel, 50% JME, and 100 ppm TiO_2
BP	:	Brake power
BTE	:	Brake thermal efficiency
BSFC	:	Brake specific fuel consumption
BP	:	Brake power

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