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Experimental Investigation on Effect of Nano Particles on Performance and Emission Characteristics of Diesel Engine Fuelled with Waste Cooking Oil Biodiesel

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Abstract

The depletion of conventional fuels and increase in global warming due to burning of conventional fuels forces scientists to develop sustainable alternative fuels which are renewable and suggested biodiesel as an immediate substitute for the conventional diesel fuel. The potential of waste cooking oil is increasing in the recent years as the people are avoiding usage of waste cooking oil (WCO). In this work, biodiesel was produced from WCO and used as partial substitute for the conventional diesel and studied the impact of titanium oxide (TiO_2) nanoparticle on engine's emission level and performance. The engine tests were conducted on compression ignition engine and from the experimental results, it was observed that the addition of Al_2O_3 enhances the engine's thermal efficiency and minimises the emission levels.

Keywords: *Biodiesel, nanoparticle, properties, engine test, performance*

1.0 Introduction

The energy demand of the globe increases exponentially in the present decade due to increase in world population, industrial activities and increase in automobiles. The energy availability also helps in the energy security and financial development of country and few countries are focussing on utilising renewable energy sources due to global warming and pollution created by burning conventional fuels. Hence there is a demand for the sustainable alternative fuel and diesel is most widely used for automotive sector and hence biodiesel is suggested as a renewable substitute.

The primary energy demand will increase till the year 2040 due to various reasons such as increases in industrial activities, population growth, etc. The energy required is obtained by burning the conventional fuel and is will directly and indirectly increases the pollutant levels and increases the global warming. The technological development in renewable energy sources reduces the initial cost and increases the energy conversion efficiency [1]. Significant number of countries started using renewable energy sources as replacement to the conventional fuels to overcome the pollution issues related to conventional fuels. The selection of renewable energy sources is based on various parameters and few important parameters such as availability, affordability and energy conversion efficiency [2].

The agricultural community started using vegetable oil / biodiesel as partial substitute for the conventional diesel fuel as it is easily available, low cost and environmentally free. Among developing countries, India imports higher quantity of conventional petroleum products and government of India has started many initiatives to promote biofuels to reduce oil import and also for energy security [3].

The unscientific disposal of waste cooking oil (WCO) may affect the environment and hence there is a demand for the conversion of WCO to useful material. The WCO can be converted into biodiesel which helps the disposal of WCO and also meets the local or regional demand of the diesel. The potential of the WCO is significant and use of WCO as substitute for the fossil diesel may reduce the demand of the fossil fuel and reduces import cost [4].

The biodiesel is produced by transesterification process and process variables should be optimised to increase the biodiesel yield and to minimise the production cost. The process variables such as molar ratio of oil to methanol, reaction time and temperature and catalyst concentration are very important, and these variables should be optimised [5]. The addition of catalyst during transesterification process increases biodiesel yield due to high surface area, base-acid property, chemical stability, etc and reduces biodiesel production cost and protects the environment. The addition of titanium oxide as heterogenous catalyst increases the biodiesel yield [6]. The use of titanium oxide as additive to the biodiesel improves the antiwear characteristics of nanofluid added biodiesel blends. fuel blends and suggested that the titanium oxide dosage should be optimised [7].

The higher NO_x emission of the nanoparticle added biodiesel blend can be reduces with the help of exhaust gas recirculation (EGR) and the EGR flowrate has to be optimised to get better engine performance and emission levels [8]. It is suggested that the NP can be added to biodiesel production and biodiesel utilisation in the diesel engine without making any modifications. The addition of NP increases yield of biodiesel from vegetable oils and enhances the performance of engine fuelled with biodiesel blend [9,10]. The addition of natural and synthetic additives improves the performance of biodiesel fuelled engine; however, it is necessary to optimise the dosage of NP as it is expensive [11,12]. The optimisation of aluminium oxide NP to the B20 blend fuelled results in better performance with lower emission levels [13]. In this work, we added titanium oxide (TiO_2) NP to the WCOB and optimised the TiO_2 to the B20 blend of WCOB.

Figure 1: WCOB

Figure 2: Nanoparticle of TiO_2

2.0 Materials and methods

In this work we have used alternative fuel as waster cooking oil biodiesel (WCOB) as a partial substitute (B20 blend) and studies the effect of WCOB on engine's emissions and thermal efficiency. We studied the effect of TiO_2 on the fuel properties of WCOB and on the performance of the engine. Three different dosage of TiO_2 was added to the B20 blend and engine tests were carried out at constant speed. The dosage of TiO_2 considered in this work are 40, 50 and 60 ppm.

3.0 Engine Tests

The engine tests were conducted on a constant speed compression ignition engine and it is a single cylinder, naturally aspirated engine. The engine tests were conducted by varying the engine load and at constant speed. No

Table 1: Specification of engine

Capacity (kW)	3.5 at 1500 rpm
Bore of the engine in mm	87.5
Stroke of the engine in mm	110
Number of cylinders	1
Cooling fluid	Water
Compression ratio	16:1
Injection time (before TDC)	23°
Number of strokes	4

Figure 3: Engine setup

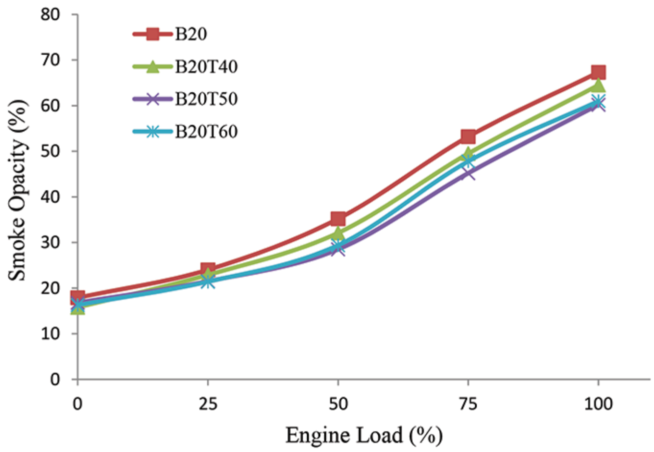

Figure 4: Smoke level at various load

modification was done in the fuel injection system and engine test observations were recorded at steady state condition. The load on the engine was varied from zero load to full load using eddy current dynamometer with an increment of 25%. A five-gas analyser was used to analyse the engine exhaust emission levels and AVL smokemeter was used for the smoke level measurement. Figure 3 shows the engine experimental set up and Table 1 depicts engine specification.

4.0 Results and Discussion

The tests on engine was conducted at steady state condition, without making any modifications in the fuel supply system. The addition of TiO_2 to the B20 blend of WCOB and diesel improves few fuel properties. Table 2 depicts the properties of fuels used in this work.

The engine's smoke emission level at different engine load conditions is shown in the Figure 4. This figure depicts that the smoke level at various load on the engine and the emission level increases with the value of load increases, due to fuel consumption increases with increase in load value. The addition of TiO_2 to the B20 blend reduces the smoke level as the TiO_2 enhances the fuel atomisation and spray formation. This behaviour is like other types of NP reported in literature [13]. Among the TiO_2 dosage, the TiO_2 dosage of 50 ppm results in lower smoke level as the optimum dosage level results in better atomisation and spray characteristics. The difference in smoke emission level at low load was small, however the difference increases as the load increases.

The engine's NO_x emission level at different engine load conditions is shown in the Figure 5. This figure shows that the NO_x level of engine at various engine load and the emission level increases with the value of load increases. The increase in fuel consumption with increase in load value results in increase in NO_x value. The addition of TiO_2 to the B20 blend increases the NO_x level as the TiO_2 enhances the fuel atomisation and spray formation which directly and indirectly enhances the combustion of the fuel. This results in higher NO_x level as the NO_x level depends upon the combustion temperature and increases in combustion temperature increases the NO_x level. Among the TiO_2 dosage, the TiO_2 dosage of 40 ppm results in lower NO_x level and the dosage of 50 ppm results in higher NO_x level.

The engine's HC emission level at various engine load conditions is shown in the Figure 6. This figure depicts that

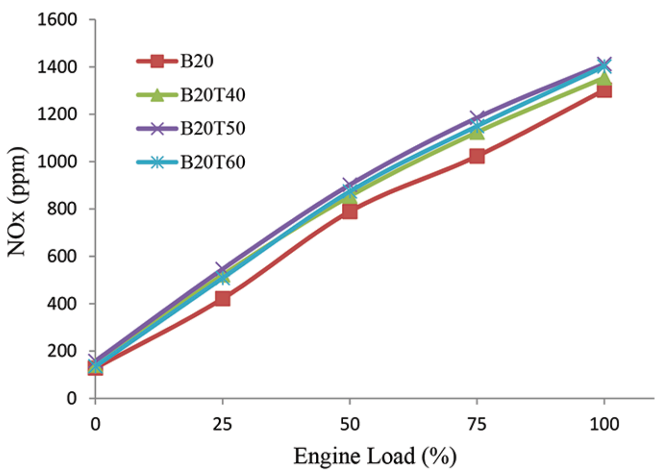

Figure 5: NO_x level at various load

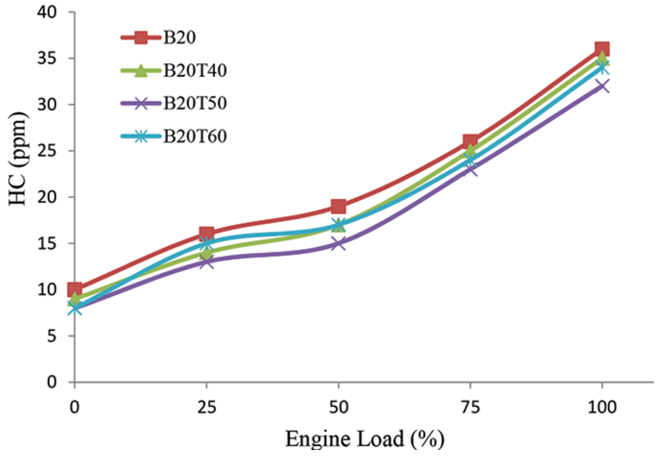

Figure 6: HC emission level at various load

the HC level of engine at various engine load and the emission level increases with the value of load increases. The increase in fuel consumption with increase in load value results in increase in HC value as the fuel consumption rate is high. The addition of TiO_2 to the B20 blend decreases the HC level as the TiO_2 enhances the fuel atomisation and spray formation which directly and indirectly enhances the combustion and reduces HC level. Among the TiO_2 dosage, the TiO_2 dosage of 50 ppm results in lower HC level.

The engine's CO emission level at various engine load conditions is shown in the Figure 7. This figure depicts that the CO level of engine at various engine load and the emission level increases with the value of load increases. The increase in fuel consumption with increase in load value results in increase in CO value as the fuel consumption rate is high. The addition of TiO_2 to the B20 blend decreases the CO level as the TiO_2 enhances the fuel atomisation and spray formation which directly and indirectly enhances the combustion of the fuel. Among the TiO_2 dosage, the TiO_2 dosage of 50 ppm results in lower CO level.

The engine's brake thermal efficiency (BTE) at various engine load conditions is shown in the Figure 8. This figure shows that the BTE value of the engine at various engine load and the BTE value increases with the value of load increases due to reduction in friction and other losses. The reduction in losses increase the useful work and results in increase in BTE value. The addition of TiO_2 to the B20 blend increases the BTE level as the TiO_2 enhances the fuel atomisation and spray formation which directly and indirectly enhances the combustion of the fuel. The better combustion increases the power output and increases the value of BTE. Among the TiO_2 dosage, the TiO_2 dosage of 50 ppm results in higher BTE level.

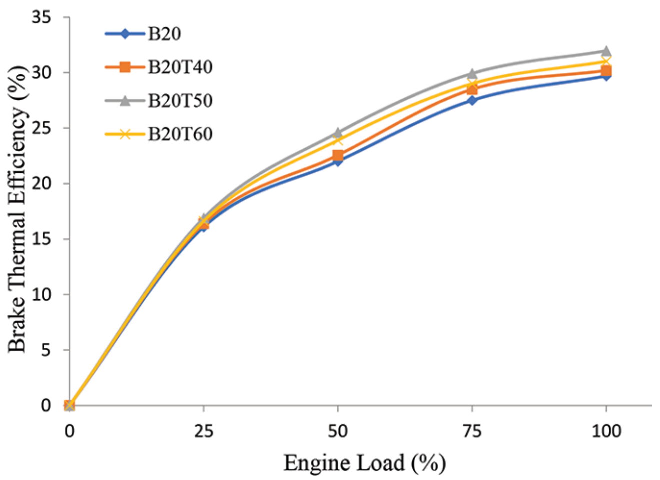

Figure 8: Efficiency at various load

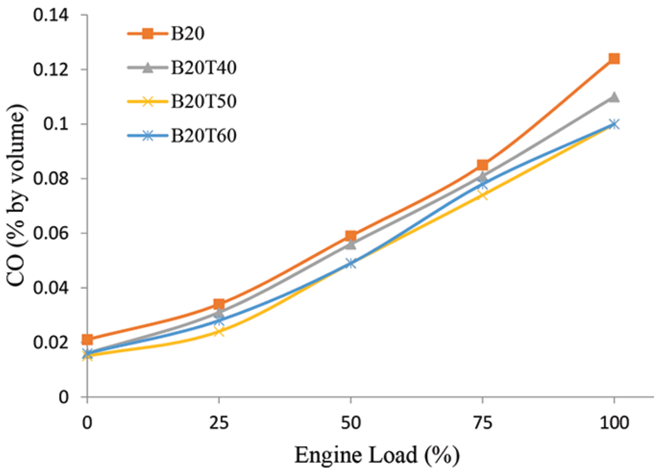

Figure 7: CO emission level at various load

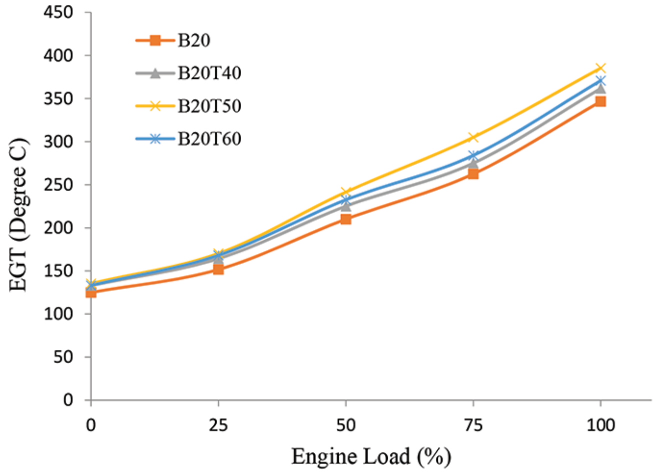

Figure 9: Efficiency at various load

The exhaust gas temperature (EGT) of the engine depicts the combustion quality and better combustion always enhances the combustion temperature which directly increases the EGT value. Figure 9 depicts the EGT value of the engine at various loads of the engine. The EGT value increases as the value of engine load increases as fuel consumption increases with increase in load. The EGT of TiO_2 added WCOB diesel blend results in higher value of EGT and it shows that the combustion improvement due to addition of TiO_2. The TiO_2 dosage of 50 ppm results in higher EGT value and 40 ppm dosage of TiO_2 results in lower EGT value.

5.0 Conclusion

The sustainable and renewable alternative fuel such as biodiesel will reduce the environmental pollution of conventional fuels. The potential of WCO is increasing in recent years and use of WCOB as substitute for the conventional diesel fuel reduce oil import and increases energy security. The addition of TiO_2 nanoparticles to the B20 blends of WCOB and diesel enhances the combustion of the fuel inside the engine. Hence there is an improvement in the thermal efficiency of the engine and significant reduction in engine emission levels. The TiO_2 dosage of 50 ppm results in lower emission levels as compared to the B20 blend of WCOB and diesel. The optimised TiO_2 dosage results in better atomisation and spray formation which results in better combustion and lower emission levels.

6.0 Acknowledgment

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