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Diesel Engine Characteristic Studies with Metal Oxide Doped Nanoparticle in Avocado Biodiesel

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ABSTRACT

Increased numbers of vehicles on road have brought about a severe problem of environment pollution and scarcity of the petroleum fuels in the recent past. Biodiesel is an attractive alternative fuel because of its environmental friendliness, ease in production and replacement potential of petroleum diesel. Biodiesel produced from a wide variety of vegetable oils is expected to supplement diesel fuel. In this work an attempt is made to produce biodiesel from a new feed stock, Avocado fruit and test its feasibility to be used as Diesel engine fuel. The main drawback of biodiesel as an engine fuel is the increased NOx emission and reduced engine performance compared to diesel fuel. Studies shown that addition of nanoparticles on fuel can reduce the NOx emission along with increased engine performance. In this work doped metal oxide nanoadditives (Al_2O_3 doped with MnO_2) were used. SEM imaging was conducted for characterization of the nanopowder. Engine test fuels were prepared by adding nanoparticles to biodiesel blend (B20) at three different concentrations (30, 60 and 90 ppm). The results of engine tests by the addition of nanoparticles showed a noticeable reduction in exhaust emissions and improvement in engine performance.

Keywords- Biodiesel, nanoparticles, NOx emission.

1. INTRODUCTION

Depletion in fossil fuels and raised environmental issues are the major concern of the public, deriving there interest to a more clean technique for energy needs. Various alternative sources have been developed of which biodiesel has been found to be a promising candidate. Biodiesel has many beneficial features of being renewable, bio degradable and providing sustainable energy [1]. Globally, there are more than 350 oil-bearing crops identified as potential sources for biodiesel production. Jatropha, Pongamia, Palm, Coconut, Soybean, Rapeseed, Cotton seed, Rice bran, Sunflower oil are a few potential feed stocks for biodiesel exploration [2, 3]. Avocado is one such feed stock which has a great potential for biodiesel exploration [4]. Blending biodiesel with diesel fuel and its utilisation in diesel engines have a predominant issue of increased NOx emissions a cause attributed to its increased density. Attempts have been made to reduce NOx emissions in biodiesel blended fuels in diesel engines by engine and fuel modifications. Increasing fuel injection pressure, retarding fuel injection timing and addition of fuel borne catalysts have shown substantial reduction in NOx emissions [5, 6]. In this study attempts have been made to use avocado biodiesel of 20% blend with diesel. Aluminium oxide doped with Manganese oxide nanoparticles was used as fuel modifier. Engine performance and emission studies have been carried at full load conditions.

2. MATERIALS AND METHODS

A single cylinder diesel engine is used in this study to evaluate the effect of nanoparticle addition on the fuel and thus the performance, fuel consumption and emissions of the engine. Three different concentrations of nanoparticles are used to evaluate change in % of fuel consumption and thermal efficiency. AVL Digas 444 model exhaust gas analyser is used to measure the engine emissions.

2.1 Biodiesel preparation

The pulp of ripe avocado fruit was dried to remove moisture. Avocado fruit contains up to 75% weight in moisture. Oil was extracted using a hydraulic press from the dried pulp. Press cake which still contains oil was subjected to solvent extraction for complete removal of oil. Chloroform and methanol 1:2 v/v was used as a solvent. Biodiesel was prepared by base transesterification with oil to methanol molar ratio of 1:9, KOH concentration of 1.5% weight of oil at 55 ±3°C for 1h. After separation of glycerin, the biodiesel was water washed thoroughly and dried. Measured physico – chemical properties of Diesel, Avocado oil and biodiesel are shown in Table 1.

Table 1 Physico – chemical properties

Property	Avocado oil	Bio diesel	Diesel	ASTM limits	ASTM Std
Kinematic viscosity (cSt)	76.52	4.9	2.3	1.9 – 6	D445
Density (kg/m^3)	924	868	839	860 - 900	D1298
Flash Point (°C)	306	173	72	>130	D93
Fire Point (°C)	359	187	79	-	D93
Calorific Value (MJ/kg)	34.23	37.83	44.8	-	D240
Acid value (mg KOH/g)	1.2	0.7	0.16	≤ 0.8	D664

2.2 *Nanoparticle preparation*

Aluminium oxide (Al_2O_3) nanoparticle was used as the base substance on to which Manganese oxide (MnO_2) was doped by co precipitation process at 0.01 mole %. The nanoparticles were dispersed in biodiesel blend using ultrasonicator. SEM image of the nanoparticle is shown in Fig. 1 and EDX spectrum is shown in Fig. 2.

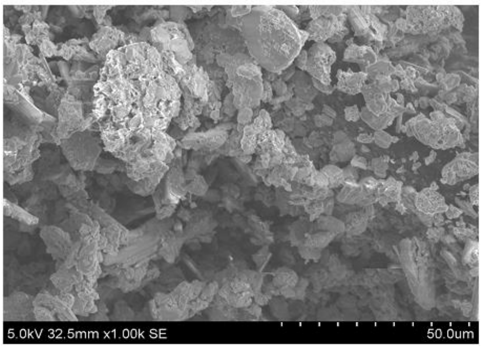

Fig. 1 SEM image of Al_2O_3 doped with MnO_2

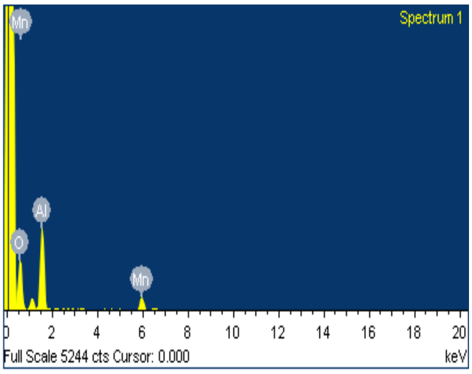

Fig. 2 EDX spectrum of Al_2O_3 doped with MnO_2

2.3 Engine Specification

A stationary single cylinder diesel engine was used in this study as shown in Fig. 3 and specifications as mentioned in Table 2. AVL Digas 444 Five Gas Analyser and AVL 437 Smoke meter were used to measure emissions and specification shown in Table 3.

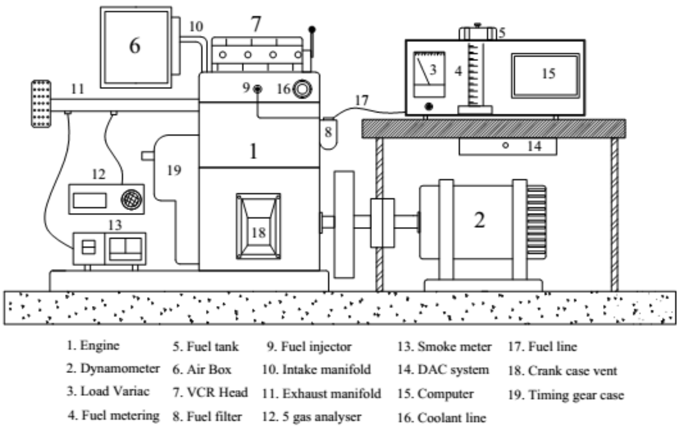

Fig. 3 Schematic diagram of test engine

Comparison of engine performance and emissions were done using Standard diesel and the following blends with diesel B20 (20% biodiesel) B20n30 (20% biodiesel with 30 ppm nanoparticle) B20n60 (20% biodiesel with 60 ppm nanoparticle) B20n90 (20% biodiesel with 90 ppm nanoparticle) at full load capacity of the engine.

3. RESULTS AND DISCUSSION

3.1 *Effect of nanoparticles on specific fuel consumption*

Change in the specific fuel consumption (sfc) is shown in Fig. 4 for different fuels at rated load. Diesel fuel has the lowest specific fuel consumption (sfc) of 0.28 kg/kWh, while B20 with the largest value of 0.33 kg/kWh.

Table 2 Test Engine Specification

Engine make	KIRLOSKAR Single cylinder
Rated brake power	3.5 kW @ 1500 rpm
Bore x Stroke	87 mm x 110 mm
Type of igmition	Compression ignition
Compression ratio	17:1
Injection pressure and timing	175 bar @23°bTDC

Table 3 Exhaust Gas Analyser Specification

Measured Quantity	Measuring Range
Carbon monoxide (CO)	0−10% vol
Carbon dioxide (CO_2)	0−20% vol
Unburnt hydro carbon (UBHC)	0−20000 ppm vol
Oxygen (O_2)	0−22% vol
Nitric oxide (NO)	0−5000 ppm vol
Smoke opacity	0−100%
Absorption	0−99 m^{-1}

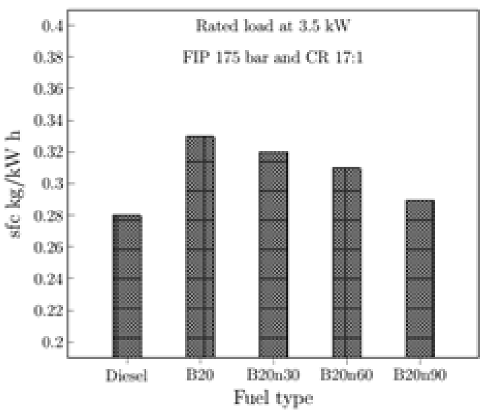

Fig. 4 Fuel type vs specific fuel consumption

A substantial reduction in the sfc was observed as the concentration of nanoparticles increases from 30 ppm to 90 ppm. A favourable condition occurs at B20n90 fuel combination where the sfc of 0.29 kg/kWh is comparable with that of diesel fuel. The presence of nanoparticles could enhance combustion and thus a reduction in sfc [7].

3.2 *Effect of nanoparticles on Brake thermal efficiency*

Change in the brake thermal efficiency is shown in Fig. 5 for different fuels at rated load. Diesel fuel has the highest brake thermal efficiency of 25.5% attributed to its higher calorific value of 44.08 MJ/kg, compared to the lowest efficiency of B20 of 23.89% due to its lower value in calorific value 38.57 MJ/kg. Biodiesel inherently have lower calorific value owing to the presence of oxygen in their fuel. However, addition of nanoparticles to the biodiesel blend shows an increase in efficiency, with 25.25% for B20n90 combination. Aluminium nanoparticles have the ability to catalyst combustion reaction. Due to its high combustion energy it causes micro explosion in the combustion chamber causing higher combustion efficiency and lower fuel consumption.

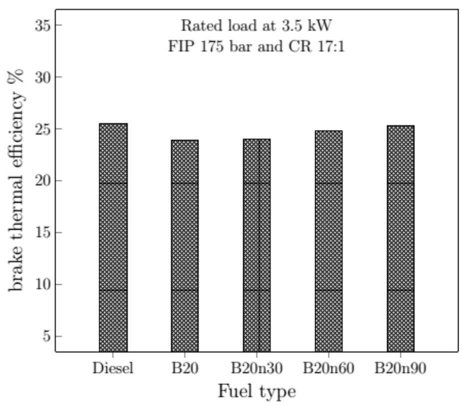

Fig. 5 Fuel type vs Brake thermal efficiency

3.3 *Effect of nanoparticles on CO emission*

Change in Carbon monoxide emission is shown in Fig. 6 for different fuels at rated load. Drastic reduction of Carbon monoxide (CO) emission was observed with B20n90 fuel combination of 0.025% volume in comparison with diesel fuel with the highest value of 0.0325% volume. A clear indication of improved combustion leading to more complete burning of fuel, aided with the influence of nanoparticles.

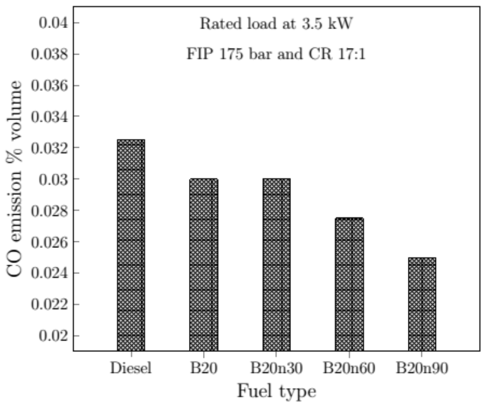

Fig. 6 Fuel type vs CO emission

3.4 *Effect of nanoparticles on CO_2 emission*

Change in the Carbon dioxide emission is shown in Fig. 7 for different fuels at rated load. The trend is quite the inverse of that of CO emission. Better combustion and more complete burning of fuel converts CO to CO_2. A maximum of 5.6% volume was observed with B20n90 fuel combination, with a least of 4.8% volume for that of diesel fuel. Anyhow it should be observed that the increase in CO_2 with biodiesel blend does not leave carbon footprint and hence a lower impact on the environment.

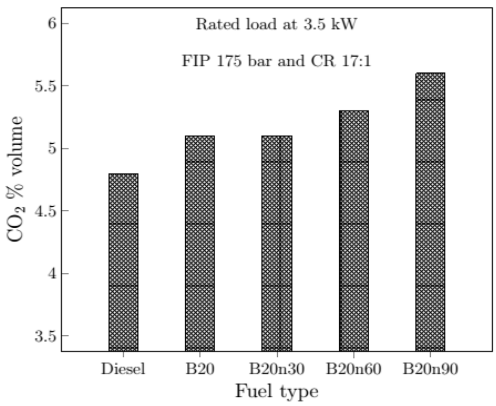

Fig. 7 Fuel type vs CO_2 emission

3.5 *Effect of nanoparticles on NOx emission*

Change in the Nitric oxide emission is shown in Fig. 8 for different fuels at rated load. Of all the other emissions, oxides of nitrogen are one were biodiesel fails in its competition with petro diesel. Diesel has the lowest NOx emission of 471 ppm in comparison with B20 of 556 ppm. Increased NOx emissions from biodiesel have been a concern and many attempts have been made to reduce this emission. Increased density of biodiesel may be one of the factors for this cause. However in this study, considerable reduction in NOx emission was observed with B20n90 fuel combination of 504 ppm, though lower than B20, still substantially higher than diesel. Manganese nanoparticles have high thermal conductivity, which helps in faster dissipation of heat in the combustion chamber. This leads to lower combustion chamber temperature, which substantially reduces NOx emissions.

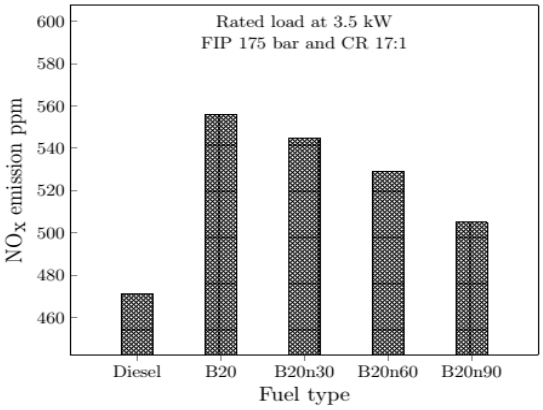

Fig. 8 Fuel type vs NO_X emission

3.6 *Effect of nanoparticles on UBHC emission*

Change in the Unburnt hydro carbon emission is shown in Fig. 9 for different fuels at rated load. The trend is like that of CO emission. Argument of reduction in CO emissions due to proper and more complete burning of fuel, eventually leads to decreased UBHC emissions. The lowest emission was observed at 6.5 ppm for B20n90 fuel combination, in comparison with diesel with a high level of 14 ppm.

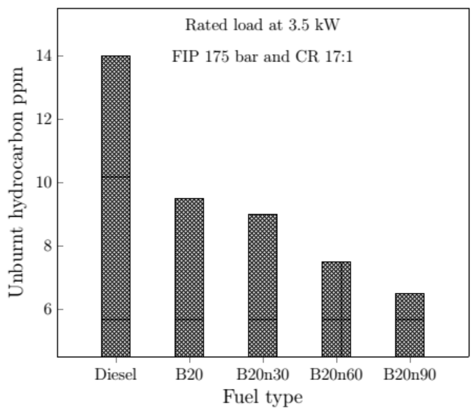

Fig. 9 Fuel type vs UBHC emission

3.7 *Effect of nanoparticles on Smoke Opacity*

Change in the Smoke opacity is shown in Fig. 10 for different fuels at rated load. B20n90 fuel combination has the lowest value of 46.45% in comparison with diesel 68.8% which is quite objectionable.

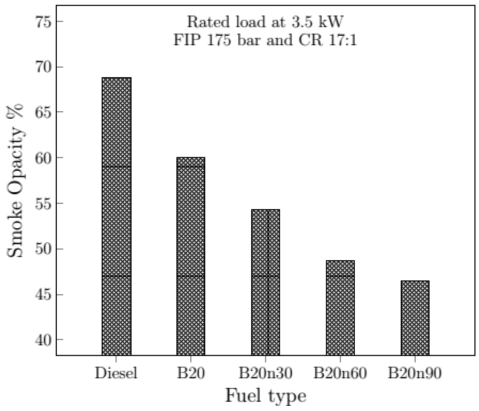

Fig. 10 Fuel type vs Smoke Opacity

4. CONCLUSIONS

Change in engine performance and exhaust emissions compared with B20 and B20n90 fuel combination is shown in Fig. 11. An increase in brake thermal efficiency of 5.7% and a decrease in specific fuel consumption by 12.1% were observed with the addition of nanoparticles. Aluminium nanoparticles have the ability to catalyst combustion reaction. Due to its high combustion energy it causes micro explosion in the combustion chamber causing higher combustion efficiency. Substantial reduction in CO, UBHC and smoke emissions of 16.6%, 31.6% and 22.7% respectively is attributed to the more complete combustion of the fuel due to the presence of nanoparticles. Though a considerable reduction of NOx emission of 9.4% was observed but which still is higher in comparison to diesel fuel. Nanoparticles doped with metal oxides have shown to improve on the property of the material, unlike straight metal oxide nanoparticles.

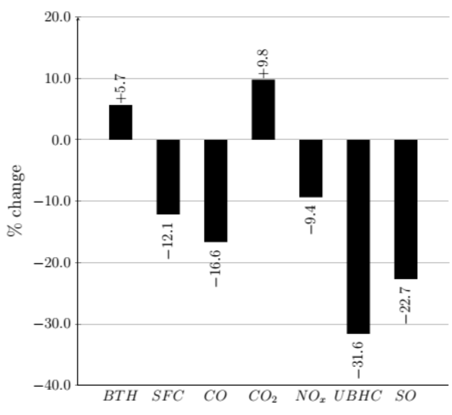

Fig. 11 Change in performance

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REFERENCES

[1] D. Rutz, R. Janssen, *Biofuel Technology Handbook*, WIP Renewable Energies Germany, *2008*.

[2] A. Atabani, T. Mahlia, I. A. Badruddin, H. Masjuki, W. Chong, K. T. Lee, Investigation of physical and chemical properties of potential edible and non-edible feedstocks for biodiesel production, a comparative analysis, *Renewable and Sustainable Energy Reviews*, 21, 2013, 749-755.

[3] B. Deepanraj, P. Lawrence, R. Sivashankar, V. Sivasubramanian, Analysis of pre-heated crude palm oil, palm oil methyl ester and its blends as fuel in a diesel engine, *International Journal of Ambient Energy*, 37(5), 2016, 495-500.

[4] G. Knothe, Avocado and olive oil methyl esters, *Biomass and Bioenergy*, 182, 2013, 1430-1442.

[5] G. Kannan, R. Anand, Effect of injection pressure and injection timing on DI diesel engine fuelled with biodiesel from waste cooking oil, *Biomass and Bioenergy*, 46, 2012, 343-352.

[6] V. Sajith, C.B.Sobhan, G.P.Peterson, Experimental Investigations on the Effects of Cerium Oxide Nanoparticle Fuel Additives on Biodiesel, *Advances in Mechanical Engineering* 07, 2010, 168-174.

[7] A.C. Sajeevan, V. Sajith, Diesel engine emission reduction using catalytic nanoparticles: An experimental investigation, *Journal of Engineering*, 17, 2013, 1- 9.

[8] M. Kannan, R. Karthikeyan, B. Deepanraj, R. Baskaran, Feasibility and performance study of turpentine fueled DI diesel engine operated under HCCI combustion mode, *Journal of Mechanical Science and Technology*, 28(2), 2014, 729-737.

[9] S. Santhanakrishnan, B.K.M. Ramani, Performance emission and combustion characteristics of a Low Heat Rejection Engine Fuelled with Diesel -CNSO-EEA Blend, *Journal of Advanced Engineering Research*, 2(1), 2015, 29-33.