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Performance and Emission Characteristics of a CI Engine Using Alumina Nano Additive Castor Oil Biodiesel- Diesel Blends

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Abstract - *In this experimental investigation alumina (Al_2O_3) nanoparticles were added to castor oil methyl ester (CME20) in different proportions to find out the performance and emission characteristics of a single cylinder, four stroke, high speed diesel engine. Castor oil methyl ester was produced by transesterification process and bended with diesel. The nanoparticles were agitated with the aid of ultrasonicator to attain uniform suspension. The experiments were conducted on a high speed diesel engine at a constant speed of 1500 rpm using different blends of alumina doped castor oil methyl ester (CME20+50ppm Al_2O_3) and (CME20+100ppm Al_2O_3) and the results were compared with the neat diesel. The experimental results showed that a substantial enhancement in brake thermal efficiency (BTE) and a marginal reduction in the harmful pollutants (such as HC, CO) for the nano additive biodiesel blends.*

***Key Words*: Alumina nanoparticles, Castor oil methyl ester, Transesterification, Performance and emissions**

1. INTRODUCTION

Owing to the dwindling of the fossil fuel reserves day by day, there is a necessity to find out an alternative source of energy which can replace fossil fuels. Petroleum fuels play an vital role in the fields of transportation, industrial development and agriculture [1].Now currently, world energy utilization is about 12.2×10^9 tons of crude oil per year. Energy utilization is estimated to raise to 1.75×10^9 tons of crude oil by 2035 [2].Many research works are going on to replace the diesel fuel with an appropriate alternative fuel such as biodiesel. Biodiesel is one of the best available sources to fulfil the energy requirement of the world [3].Rudolf Diesel tested peanut oil as fuel for his engine for the first time on August 10, 1893.Since then, the biodiesel concept came into existence [4].Biodiesel is the name of a clean burning alternative fuel, produced from domestic, renewable resources. Biodiesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a biodiesel blend. It can be used in compression-ignition (diesel) engines with little or no modifications. Biodiesel is simple to use, biodegradable, nontoxic and essentially free of sulphur and aromatics [5].Biodiesel can be produced from edible and non-edible vegetable oil, algae, animal fats, grease and even from waste cooking oil. Currently, non-edible vegetable oil has become an attractive feed stock for biodiesel production, since it is lower in price compared to edible oil and easily available. The prime feedstock for the production of biodiesel in India can be non-edible oils which obtained from plant species such as Ratanjot (Jatropha curcus), Karanja (Pongamia pinnata), Neem (Indica) and Castor (Ricinus communis).India is the world's largest producer and exporter of castor oil. India annually exports around 2.0-2.4 lakh tons of commercial castor oil. Castor plants can grow well under hot and humid tropical conditions without any fertilizer [6].Castor plants are cultivated about 7, 00,000 hectares of land, mostly in Gujarat and Andhra Pradesh under rain fed conditions. The return in terms of oil varies from 350 to 650 kg of oil per hectare. The advantage of Castor is that its growing period is much shorter than that of Jatropha and Pongamia and there is considerably greater experience and awareness among farmers about its culture [4].Biodiesel is an oxygenated diesel engine fuel that can be obtained by conversion of the triglycerides to esters via transesterification. Transesterification is a process of using an alcohol, viz. methanol, ethanol or butanol in presence of a catalyst, such as sodium hydroxide (NaOH) or potassium hydroxide (KOH), which is chemically breaks the molecule of raw renewable oil into methyl or ethyl esters of the renewable oil with glycerol as a byproduct, reducing the viscosity of the oil. As the properties of this oil are very much similar to diesel [7].Recently, many researchers focused their attention on fuel formulation technique for achieving better performance and emission characteristics among the recent fuel additives to biodiesel, the nanoparticles as additive in biodiesel has emerged as a new promising fuel additive for achieving utmost improvement in the performance and level best reduction of exhaust emission [8]. Sadhik Basha J, Anand RB, [9] studied the effect of alumina nanoparticles as additives in the water diesel emulsion fuel on working characteristics of a diesel engine at a constant speed of 1500 rpm and found significant reduction of UBHC, CO and NO emissions for the alumina nanoparticles dispersed water diesel emulsion fuel compared to the neat water diesel emulsion fuel.

In this experimental investigation alumina nanoparticles were doped in different proportions (50 and 100 ppm) to a biodiesel blend (CME20) to find out the performance and emission characteristics of high speed diesel engine at an average constant speed of 1500 rpm at different loads and the obtained results were compared with neat diesel.

2. Materials and Methods

2.1 Preparation of Biodiesel (CME) from Castor oil

Castor oil was procured from the local market and the biodiesel was prepared by transesterification process as shown in Fig.1.

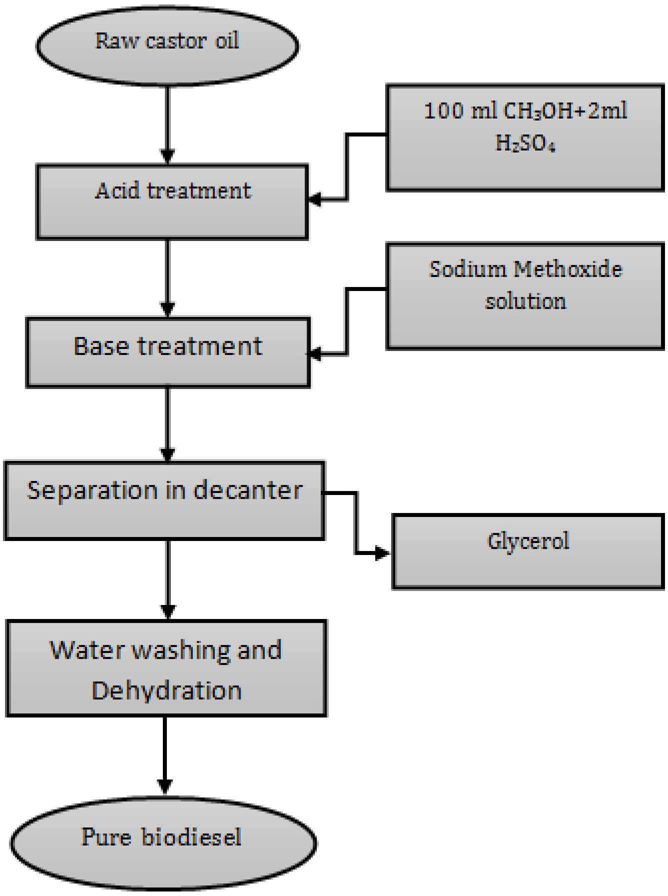

Fig-1: Flow chart of transesterification process

The filtered castor oil of one litre was heated to 45°C and 100ml Methanol (CH_3OH) is added per one litre oil, stirred for 5-10 minutes and 2ml Sulphuric acid (H_2SO_4) is added to the mixture and heated at 60°C one hour. The mixture is allowed to settle for 2hours in a decanter to remove pulp, again it was heated up to 45°C and then sodium methoxide solution (6-7 grams of NaOH pellets is added to 250 ml of CH_3OH and stirred thoroughly) is added to the mixture and heated up to 60°C for one and half hour and then mixture is poured in to decanter allowed to settle for 6 -8 hours. The glycerol content is separated by water washing with distal water, finally the mixture is heated up to 110°C to remove moisture present in the biodiesel and cooled down to room temperature.

2.2 Preparation of nanoparticles blended Castor oil Methyl ester

The alumina nanoparticles are weighed to a predefined mass fraction of 50 ppm and 100 ppm and dispersed in the biodiesel blend with the aid of ultrasonicator set a frequency of 20 kHz for 30 minutes as shown in Fig.2.The obtained fuel samples are named as B20+50ppm Al_2O_3 and B20+100ppm Al_2O_3.The blended fuel samples are characterized and their properties are tabulated in Table -1

Fig-2: Ultrasonicator

Table-1 Properties of tested fuel samples

Fuel sample	Kinematic viscosity @40°C (cSt)	Flash point (°C)	Fire point (°C)	Calorific value (MJ/kg)
Diesel	3.12	48	54	42.0
B20	4.20	74	82	40.19
B20+50ppm Al_2O_3	4.28	74	83	40.23
B20+100 ppm Al_2O_3	4.37	73	82	40.26

3. Experimental setup and procedure

In this experimental analysis a single cylinder, four stroke, water cooled, constant speed, high speed diesel engine with a rope brake dynamometer is used as shown in Fig.3. The engine specifications are given in Table-2, air consumption was measured with the help of air box with small orifice is provided at the air inlet. The fuel consumption was measured on volumetric basis using a burette and stopwatch. The exhaust emissions are measured by using 5-Gas analyzer during steady state condition. The experiments are conducted with diesel, B20 and alumina nano additive biodiesel blends.

Fig-3: Experimental setup

Table -2 Specifications of the Test Engine

Make and model	Kirloskar & AV-1
Bore (mm)	80
Stroke (mm)	110
Speed (RPM)	1500
Brake power (HP)	5
Compression ratio	16.5:1
Loading type	Mechanical

4. Results and discussion

Engine performance and emission characteristics results are analyzed for diesel, B20, B20+50ppm Al_2O_3 and B20+100ppm Al_2O_3 test fuels, and results are discussed in the following section.

4.1 Performance characteristics

4.1.1 Brake specific fuel consumption (BSFC)

It has been observed from Fig.4.that the BSFC for castor biodiesel-diesel blends and neat diesel tested, BSFC decreases with increase in load. The BSFC for all biodiesel blends along with diesel increased initially at low loads and decreased at maximum load condition. The BSFC of biodiesel blends was increased throughout the operating range as compared to neat diesel. This is mainly due to the higher viscosity, lower calorific value and higher density of the fuel blends [4]

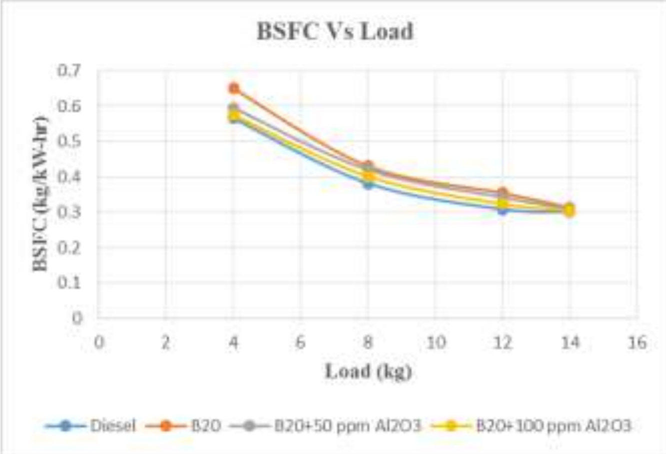

Fig-4: Variation of Specific fuel consumption with Load

The minimum value of BSFC for diesel and B20+100 ppm Al_2O_3 are 0.301 kg/kW-hr and 0.305 kg/kW-hr respectively at maximum load.

4.1.2 Brake thermal efficiency (BTE)

It can be observed from Fig.5.That the BTE increases with the load for both CME20 and Al_2O_3 blended CME20.The BTE of the B20+100 ppm Al_2O_3 better than that of other fuel blends.

The BTE increased by 0.88% and 1.43% for B20+50 ppm Al_2O_3 and B20+100 ppm Al_2O_3 respectively at maximum load.

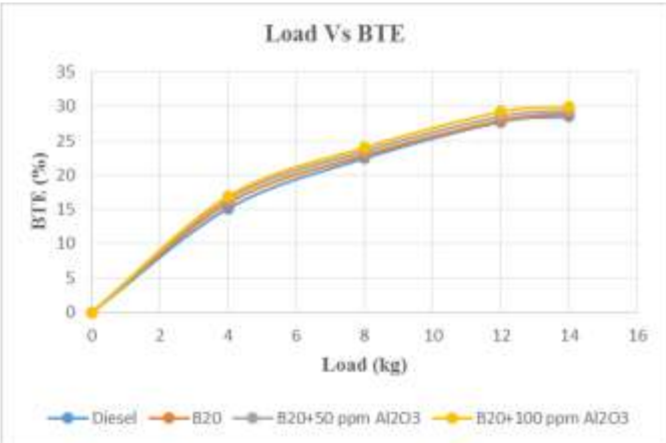

Fig-5 Variation of Brake thermal efficiency with Load

4.2 Emission characteristics

4.2.1 Nitrogen oxide (NO_X) emissions

It can be observed from Fig.6.The NO_X levels increased with the increasing the load for all fuel blends including neat diesel. The fuel blend B20+50ppm Al_2O_3 has given lower NO_X emissions compared with all tested fuel samples.

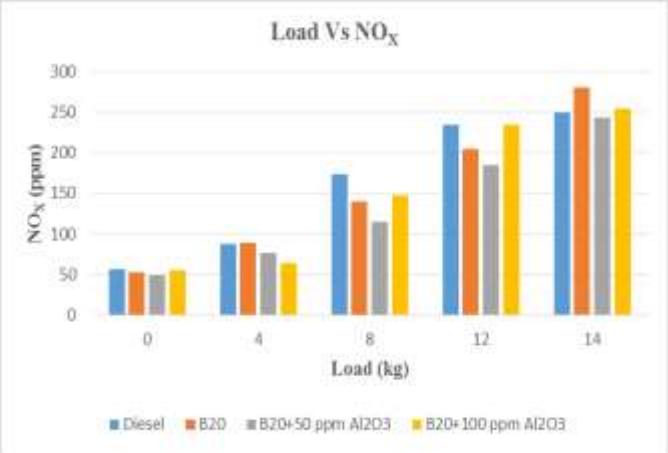

Fig-6: Variation of Nitrogen oxide emissions with Load

4.2.2 Hydrocarbon (HC) emissions

It has been observed from Fig.7.The HC levels are less for B20 and alumina nano additive biodiesel blends compared to neat diesel because of Al_2O_3 nanoparticles supplies the oxygen for the oxidation of hydrocarbon and CO during combustion. Diesel fuel had more HC emissions compared to all fuel blends at maximum load.

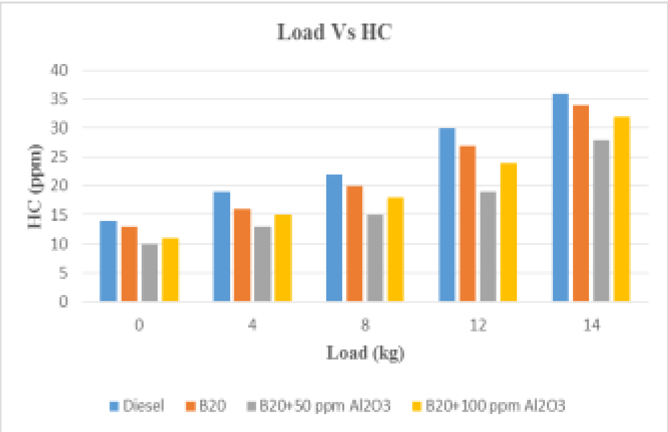

Fig-7: Variation of Hydrocarbon emissions with Load

4.2.3 Carbon monoxide (CO) emissions

Fig.8. shows that when increasing the load CO levels are increased. Compared to the neat diesel at all loads the CO levels are less for B20+50ppm Al_2O_3.It indicates complete combustion.

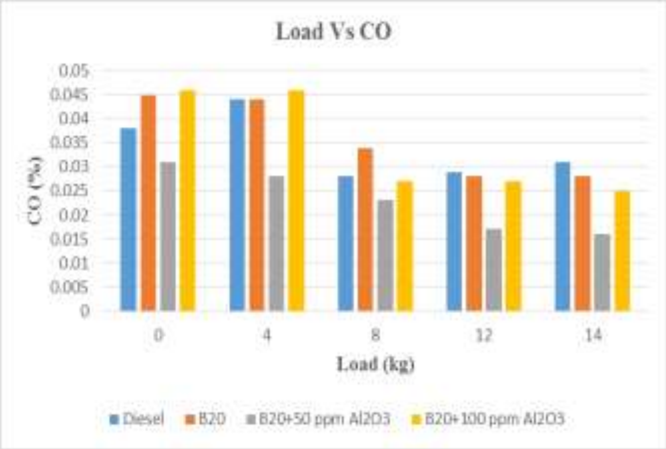

Fig-8: Variation of Carbon monoxide emissions with Load

4.2.4 Carbon dioxide (CO_2) Emissions

It has been observed from Fig.9. The CO_2 concentration increased with increase in load. Compared to diesel at all loads the CO_2 emissions are more for alumina added biodiesel blends. The alumina resulted in complete combustion and formation of CO_2.

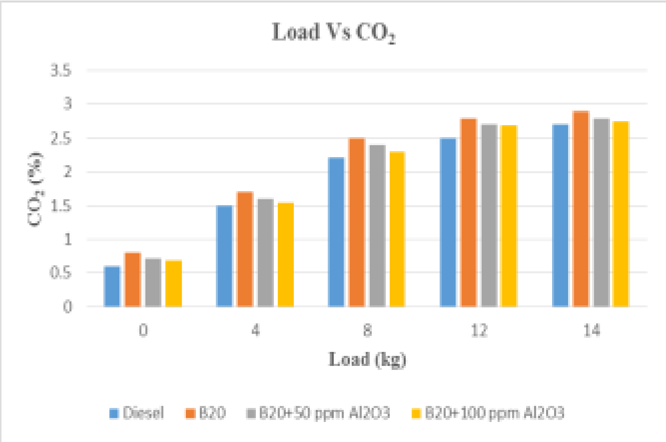

Fig-9: Variation of Carbon dioxide emissions with Load

5. CONCLUSIONS

Based on the above experimental analysis the following conclusions are obtained

1. The BTE increases by 0.95 to 1.43% with the addition of Al_2O_3 nanoparticles to the B20 blend compared to diesel.

2. The BSFC is more for B20 blend compared to all tested fuel samples.

3. The fuel sample B20+50 ppm Al_2O_3 has given lower NO_X emissions compared to all test fuel samples.

4. The HC emissions are less for alumina added biodiesel blends, B20+50 ppm Al_2O_3 has given less HC emissions compared to all fuel samples.

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