

The Experimental Investigation on Performance and Emission Characteristics of a Single Cylinder Diesel Engine using Nano Additives in Diesel and Biodiesel

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Abstract

Objective: To determine the engine performance and emissions of a single cylinder Direct Injection (DI) diesel engine using diesel-biodiesel blends with nano additive. **Method:** Blends of diesel-biodiesel of different proportions are prepared, to which Nano additive Cerium Oxide (CeO_2) is added. Properties like Flash point, Fire point, Calorific values are established for these blends. This fuel is used in single cylinder Direct Injection (DI) 4-stroke diesel engine and performance of the engine is recorded along with emission details. **Finding:** In this present investigation cotton seed oil is taken as base oil (biodiesel) and Cerium Oxide (CeO_2) as Nano additive. By using by using different blends of cotton seed oil methyl esters, for which Cerium Oxide (CeO_2) Nano additives of size 30-50 nm is added in different proportions with neat diesel fuel. The experiments were conducted on a single cylinder Direct Injection (DI) 4-stroke diesel engine, and observed the variation of Specific Fuel Consumption (SFC), Brake Thermal Efficiency, Air-Fuel ratio, Exhaust Gas Temperature (EGT), NO_x emissions, Carbon Monoxide (CO), and Hydro Carbons (HC) emissions. **Conclusion:** The results have shown lower fuel consumption, better performance, and lower emissions of Carbon Monoxide (CO), Hydro Carbons (HC) but higher emissions of (NO_x), in comparison to neat diesel fuel.

Keywords: Biodiesel, Engine Performance, Exhaust Emissions, Nano Additive

1. Introduction

Diesel engines are widely used for their low fuel consumption and better efficiency. As the world's petroleum supplies are becoming constrained, attention has been directed to find out alternate fuels for engines. After the 1973 oil embargo, it had been very important to study the alternative sources of fuel for diesel engine because of the concern over the availability and the price of petroleum based fuels. The present reservation of fuels used in Internal Combustion (IC) engines including diesel will deplete within 40 years if consumed at an increasing rate estimated to be of the order of 3% per annum. All these aspects have drawn the attention to conserve and stretch the oil reserves by way of alternative fuel research.

1.1 Diesel Engines

Diesel engine is internal combustion compression-ignition engine, in which air is drawn in to the cylinder which is compressed to the set compression ratio, where fuel (diesel) is injected which burns due to the heat acquired by air in compression resulting working stroke of 4-stroke/2-stroke engine. Thermal efficiency of diesel engine is higher than any IC engine of the same capacity due to high compression ratio and dissipation by excess air.

Diesel engines replaced steam engines due to their better efficiency. These are developed as early as 1910 and are used widely in locomotives, road transportation vehicles, ships and for running heavy equipment and also for electricity generation.

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1.1.1 Basic Size Groups based on Power

There are three basic size groups of diesel engines based on power. There are small, medium, and large. The small engines have power-output values of less than 188 kilowatts. This is the most commonly produced diesel engine type. Medium engines have power capacities ranging from 188 to 750 kilowatts, and the large diesel engines have power ratings in excess of 750 kilowatts.

1.1.2 Based on Number of Strokes

There are two basic types of Diesel Engines based on number of strokes. Those are four stroke cycle and two stroke cycle.

1.1.3 Based on Speed

Within the diesel engine industry, engines are often categorized by their rotational speeds into three unofficial groups those are high-speed engines ($> 1,000$ rpm), medium-speed engines (300–1,000 rpm) and slow-speed engines (< 300 rpm).

1.2 Biodiesel

Biodiesel is mono-alkyl ester produced through trans esterification, a process; in which heating of vegetable oils take place in the presence of a catalyst.

Biodiesel helps to reduce pollution by lower exhaust emissions. It can be used pure or can be blended with petroleum diesel fuel in various proportions. It can be used in existing C. I. engines with practically no modifications.

1.2.1 Methods of Biodiesel Production

The biodiesel production process, starts with collecting oil seeds from oil plants (oil trees). The oil getting from oil seeds, which is raw oil, is converted in to biodiesel using Distillation, Pyrolysis, Emulsification and Tran's esterification processes.

1.2.2 Advantages of Bio Fuel

Some of the advantages of using biodiesel are reducing dependency on foreign petroleum, greenhouse gas emissions and air pollution, and it helps to domestic and rural economy, provides fuel at cheaper rate and create regular employment.

1.3 Nano Additives

In nano technology, additives of nano size change the behaviour of entire product significantly.

Classification is based on particle size and as observed ultrafine particles of size 1-100 nm, fine particles of size 100-2500 nm and the coarse particles of size 2500-10000 nm. Ultrasonicator which is used to mix the fuels (diesel, biodiesel and Nano additive) is shown in Figure 1.



Figure 1. Ultrasonicator instrument.

The sonication bath improves the mixing property of cerium oxide with fuel blends. Cerium oxide is insoluble in water and other chemical solvents. The direct mixing of cerium oxide and ethanol leads to complete settle down of Nano particles as shown in Figure 1. The cerium oxide diluted only in strong acids like sulphuric acid and Nitric acid. But this concentrated acid enters inside the engine; corrode the engine cylinder as well as results in high moisture content which leads to knocking and detonation which reduce the performance and results in high emissions. At second stage ultrasonic bath leads to improve the mixing property of ethanol with cerium oxide by using sonication. By using vibrational bath Cerium Oxide-Ethanol blends is prepared.

2. Literature Survey

For this project, relevant topics from various journal papers are studied and summarized have under literature survey.

Pushparaj and Ramabala¹ in this paper In this paper the Cashew Nut Shell Liquid (CNSL) was selected for biodiesel, ethanol and diethyl ether as additives.

Ethanol and diethyl ether are used as additives to diesel/biodiesel blends and found their effect on the emission and performance of direct injection unmodified diesel engine. Biodiesel was made by pyrolysis process. The experimental results showed that the engine performance is improved and the exhaust emissions NO are reduced as compared to conventional diesel fuel.

The effect of Nano-fuel additives² in this investigation Jatrophaoil is used as biodiesel and [Magnalium (Al-Mg) and cobalt oxide (Co_3O_4)] is used as nano additive with particles size ranging from 38-70 nm. This is used in a single cylinder, air cooled, direct injection diesel engine and performance and emission characteristics are observed. By experimental results it is found that NO_x emissions are reduced with the addition of nano additives. HC emission and CO emission are reduced for B100 with additive at part load and full load conditions respectively.

Manikandan and Sethuraman³ this paper contains an experimental investigation carried out to establish the performance and emission characteristics of single cylinder diesel engine by using ethanol-ceric oxide blend. The performance and emission characteristics are studied. This investigation depicts that the catalytic action of cerium oxide provides oxygen for the oxidation of CO and absorbs oxygen for the reduction of NOx. Carbon deposits within the engine cylinder are burnt off by Ethanol-cerium oxide, thereby eliminating deposition of compounds on the cylinder wall which in turn results in reduction of HC emissions.

Chandan Kumar et al.⁴ in this paper Nitro Methane (NM) is the additive with diesel, which is used in single cylinder 4-stroke C.I engine. The performance and emission characteristics of the engine compared at compression ratios 17.5:1 and 16.5:1 with additive and without additive, and observed that the better results are obtained by compression ratio 16.5:1.

Shaaafi and Velraj⁵ in this experimental investigation soybean oil is taken as biodiesel and alumina (Al_2O_3) is added at Nano size. Ultrasonicator is used for mixing nano additive and biodiesel with a suitable surfactant. The results are compared with neat diesel fuel. From the results obtained in this investigation, it was observed that the exhaust gas temperature decreases, brake thermal efficiency increases, the mixing capabilities of the nanoparticles increases, the CO and HC emissions decrease appreciably. But at full load condition there is a slight increase in NO_x .

S. Imtenan et al.⁶ in this paper Jatropa oil is used as biodiesel and Engine tests were conducted at variable speeds, ranging from 1000 rpm to 3000 rpm at constant 80 N m torque on a 4-cylinder turbocharged indirect injection diesel engine. The results shown are in the increase in performance, low SFC and reduce the diesel engine emissions.

Md. Nurun Nabi et al.⁷ in this work, cotton seed oil is taken as biodiesel and blended with diesel fuel. For various blends it is found that emissions like Carbon Monoxide, Particulate matter and smoke are found comparatively less. But nitrogen (NO_x) emissions found slightly increased.

Murat Karabektas et al.⁸ in this paper Cottonseed Oil Methyl Ester (COME) is taken as biodiesel. The tests were carried out at full load conditions in a single cylinder, four-stroke, direct injection diesel engine. Before supplying to the engine, COME is preheated to four different temperatures, namely 30, 60, 90 and 120°C. With different fuel blends, performance increment and emissions decrease are found.

D. H. Qi et al.⁹ in this paper rapeseed oil is used as biodiesel and ethanol with a surfactant (oleic acid/1-butanol mixture) as additive. By experiments it is observed, that with the increase in ethanol volume fraction, the viscosity and density of the prepared fuels decrease. With increase in ethanol volume, Break Specific Fuel Consumption (BSFC) of hybrid fuel increases and smoke emission decreases in comparison with that of pure diesel. The emissions are lower than those for diesel fuel at high engine loads and the NO_x emissions were almost similar to the diesel fuel, but CO and HC emissions are more at low engine loads.

Md. Nurun Nabi et al.¹⁰ in this work neem oil is taken as biodiesel fuel. Experiments are conducted on naturally aspirated, direct injection diesel engine with diesel fuel and diesel-biodiesel blend. With diesel-biodiesel blend it is found lower carbon monoxide (CO) and lower smoke emissions in comparison to that of diesel fuel. But higher oxides of nitrogen (NO_x) are emitted when compared to that with neat diesel fuel. With the EGR process NO_x emissions was slightly reduced even with diesel-biodiesel blends.

Mallikappa D. N. et al.¹¹ in this paper cardinal oil is taken as biodiesel and the engine tests were conducted on a double cylinder, direct injection, compression ignition engine. The experimental results are observed that the brake power

increases as load increases. Brake specific energy conversion decreases with increase in brake power. Brake thermal efficiency increases with higher brake power and emission levels (HC, CO, NO_x) were nominal to fuel blends.

Y. V. Hanumantha Rao et al.¹² in this paper Jatropha oil is taken as biodiesel and Multi-DM-32 is used as additive. By the experiments it is observed, that the brake thermal efficiency of an engine slightly increases in diesel and its blends and exhaust gas temperature was increases. The emissions are (CO₂, CO, smoke) decreases in biodiesel operation compared to neat diesel fuel.

3. Problem Definition and Experimental Procedure

The fossil fuels are depleting at faster rate, there is a need to search for alternate fuels and the performance improvement methods. The main aim of this work is to evaluate the performance of biodiesel with influence of nanoparticles in DI diesel engine. The cotton seed oil is taken as the base oil (biodiesel oil) and the cerium oxide is taken as Nano additive (CeO₂) in this work.

3.1 Proposed Work

Lot of research is being done to achieve better engine performance, using biodiesel derived from vegetable

oil which is optimally mixed with diesel resulting in low emissions and thereby reducing the fossil fuel consumption. The block diagram of proposed work is as shown in Figure 2. The recent pioneering advancement in nanotechnology made the fuel researchers to search for suitable Nano additives as catalysts, to further improve the engine performance and also to reduce the emissions. In this direction, an attempt is made in the present research to study the combustion, engine performance and emission characteristics of the six modified fuels prepared, and a comparison is made with neat diesel.

3.2 Experimental Procedure

Cottonseed oil is taken as biodiesel and diesel-biodiesel blend is used for finding out the performance of the direct injection diesel engine. Maximum 50 per cent of biodiesel is mixed with diesel to balance viscosity. In this investigation, Cerium Oxide (CeO₂) is taken as Nano additive to the diesel-biodiesel blend and performance tests are conducted on the same engine.

After checking engine condition along with lubricating oil level, metered gravity of fuel is supplied to the engine on its start and engine is run initially for 30 minutes to pick up the rated speed. The experiments are to be conducted at 0, 1/4, 2/4, 3/4 and maximum loads. Fuel consumption rate is noted. The above procedure is repeated for all fuel samples.

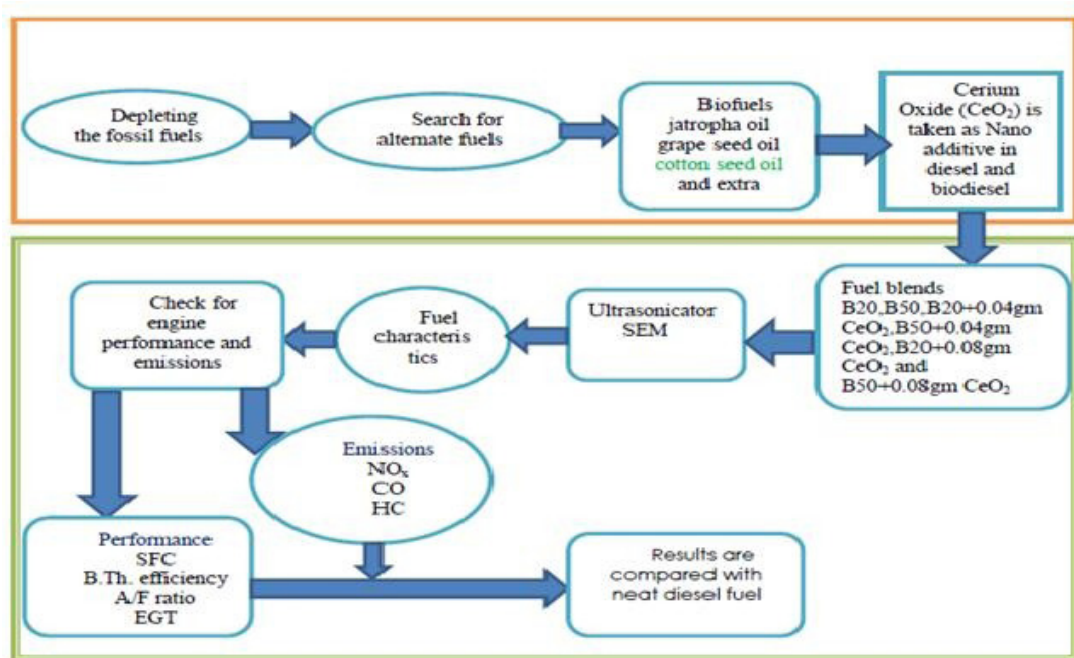


Figure 2. Block diagram of proposed work.

3.3 Biodiesel Blends

The cottonseed oil biodiesel is utilised to prepare the blends and Cerium Oxide (CeO_2) is used as Nano additive and is used in different proportions. The properties of fuel and blends are given in Table 1.

Table 1. Properties of fuel and fuel blends

Fuel	Flash point ($^{\circ}\text{C}$)	Fire point ($^{\circ}\text{C}$)	Calorific value (kJ/kg)
Diesel	53	58	43800
B20	87	94	41050
B50	108	118	40500
B20+ 0.04gm CeO_2	81	84	41162
B50+ 0.04gm CeO_2	93	96	40980
B20+ 0.08gm CeO_2	76	82	41134
B50+0.08gm CeO_2	94	98	40957

The following are the fuel samples, Diesel, B20 (80 percentage diesel and 20 percentage biodiesel in volume), B50 (50 percentage diesel and 50 percentage biodiesel in volume), B20+0.04 gm CeO_2 (80 percentage diesel and 20 percentage biodiesel and 0.04 gm (40 mg/l) cerium oxide) in volume, B20 + 0.08 gm CeO_2 (80 percentage diesel and 20 percentage biodiesel and 0.08 gm (80 mg/l) cerium oxide) in volume, B50 + 0.04 gm CeO_2 (50 percentage diesel and 50 percentage biodiesel and 0.04 gm (40 mg/l) cerium oxide) in volume, B50 + 0.08 gm CeO_2 (50 percentage diesel and 50 percentage biodiesel and 0.08 gm (80 mg/l) cerium oxide) in volume respectively and the total no of experiments are 28. All the fuel blends are shown in Figure 3.



Figure 3. Sequence of blends B20, B50, B20-0.04 gm, B20-0.08 gm, B50-0.04 gm, B50-0.08 gm.

3.4 High Speed Diesel Engine

In this present investigation 4-stroke, single-cylinder water-cooled, naturally-aspirated and Kirloskar made

diesel engine is used. Its compression ratio is 18:1. The specification of engine power is 3.68 kW at 3000 rpm. The following are a single cylinder four stroke diesel engines is as shown in Figure 4 and the engine specifications observed in Table 2.



Figure 4. Single cylinder high speed diesel engine.

Table 2. Engine specifications

Engine specifications	
No. of cylinders	1
Brake power	5HP
RPM	3000rpm (constant)
Bore	78mm
Stroke	68mm
Loading type	Eddy current dynamometer
Drum diameter	0.315m
Orifice Diameter	20mm

4. Results and Discussion

The results are very encouraging and reported in detail in this paper. Some of the salient results are summarized below.

4.1 Specific Fuel Consumption (SFC)

The performance is also given in terms of SFC at various loads, as these parameters directly indicate the mass of fuel consumed per unit power output. Figure 5 shows the variation of the Specific Fuel Consumption (SFC) with load. It is seen from the figure that for all the tested fuels, the specific fuel consumption less in lower loads and with an increase in load it is equal to the diesel fuel. This is because lower calorific value of these fuels, compared to neat diesel.

4.2 Break Thermal Efficiency (BTE)

Break Thermal Efficiency (BTE) is plotted against load variation which is shown in Figure 6. It is evident from the plot that increase of BTE of the engine with the increase in the load for diesel-biodiesel blend with Nano additive (Cerium Oxide (CeO_2)) compared to that of diesel and diesel-biodiesel blend. At full load operation B20-0.04 gm fuel BTE is approximately 2% higher than diesel.

4.3 Air Fuel (A/F) Ratio

Variation of Air Fuel Ratio is plotted against varying loads as shown in Figure 7. It was observed that the engine Air-Fuel ratio is decreased with increasing load and power

for diesel-biodiesel blend and diesel-biodiesel blend with the addition of Nano additive (Cerium Oxide (CeO_2)) compared to that of diesel fuel.

4.4 Exhaust Gas Temperature (EGT)

The variation of EGT with different loads for all seven fuels was shown in Figure 8. The EGT of the engine decreases with increasing load for diesel and biodiesel and its blends with the addition of Nano additive (Cerium Oxide (CeO_2)). It was observed that EGT at full load operation is decreasing simultaneously with increase in load compared to neat diesel fuel.

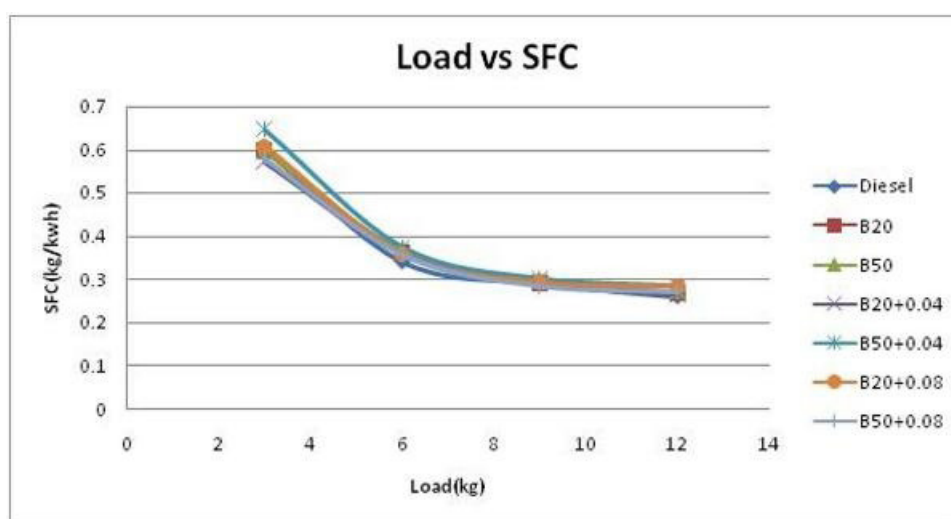


Figure 5. Load vs. SFC at different blends.

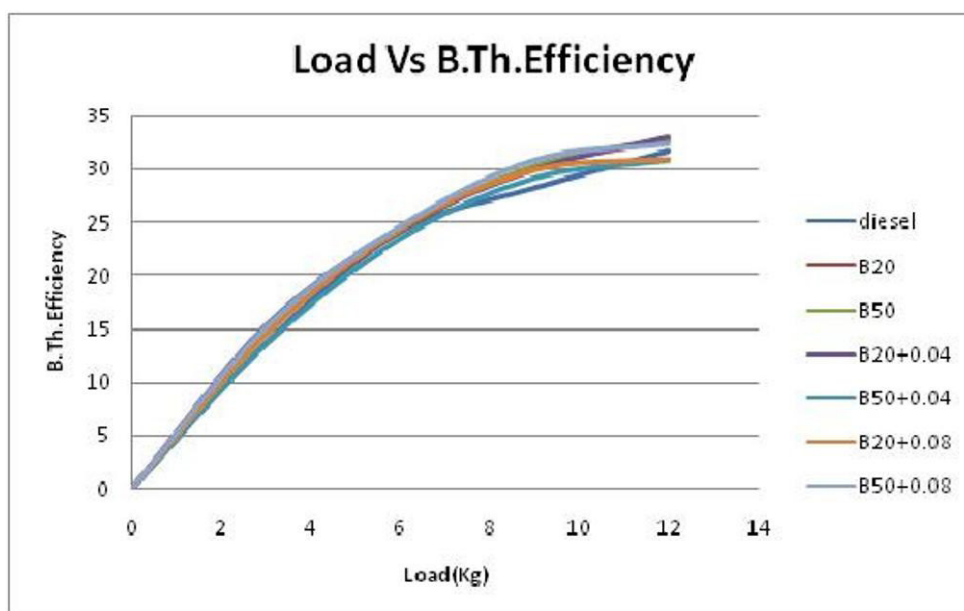


Figure 6. Load vs. B.Th. efficiency at different blends.

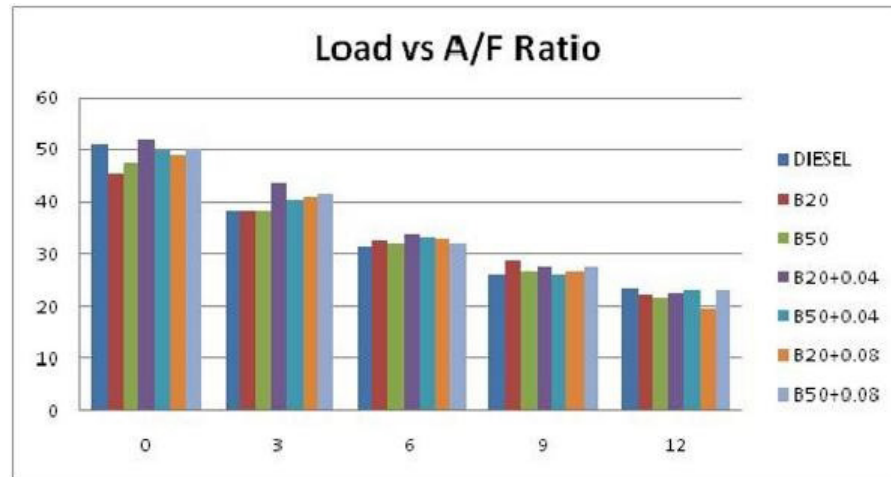


Figure 7. Load vs A/F ratio at different blends.

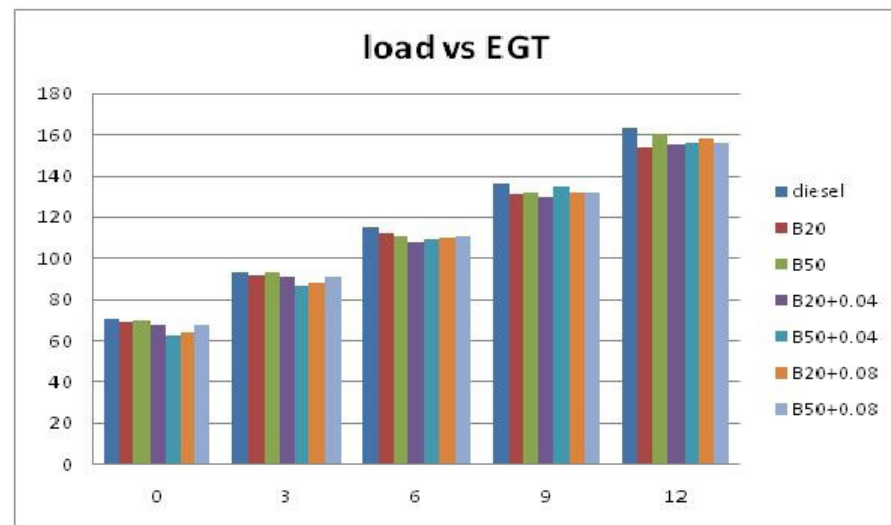


Figure 8. Load vs. EGT at different blends.

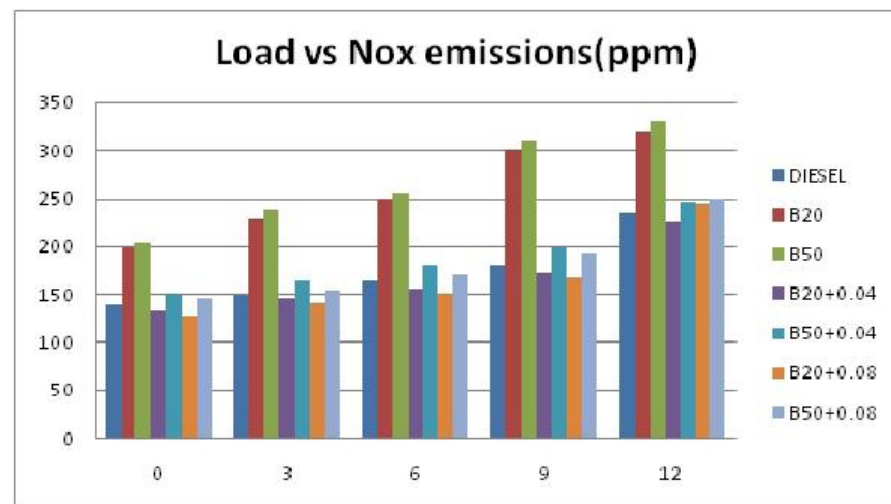


Figure 9. Load vs. No_x emissions at different blend.

4.5 Exhaust Emissions

4.5.1 NO_x Emission

Figure 9 shows the parts per million (ppm) variations of the NO_x emissions of the test engine for cotton seed oil and its different blends with reference to diesel fuel. It is seen that the cotton seed oil and its different blends operations usually it is evident from plot that NO_x emissions are less with samples B20 + 0.04 gm CeO_2 and B20 + 0.08 gm CeO_2 compared to diesel fuel. NO_x emissions with other samples are higher compared to diesel fuel. The maximum increase in NO_x emissions were obtained in the case of B50 blend.

4.5.2 CO Emission

CO emissions are plotted for diesel and diesel-biodiesel-nano additive fuels as shown in Figure 10. Due to incomplete combustion of fuel, CO is formed in the combustion process. With sufficient air supply, it can be converted to CO_2 . CO will also be formed due to low gas temperature. CO emission is high with rich-fuel mixture compared to lean mixture. CO emission is less for diesel-biodiesel-nano additive fuel compared to that of diesel. Because of biodiesel's enhanced oxygen content CO emission is reduced which is converted into CO_2 . To increase the load the CO emissions will decrease compared to diesel fuel.

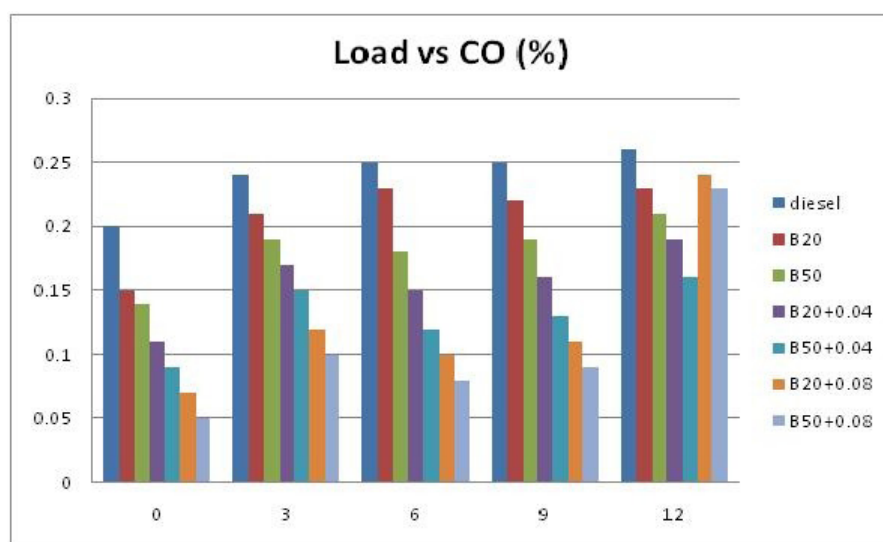


Figure 10. Load vs. CO emissions at different blends.

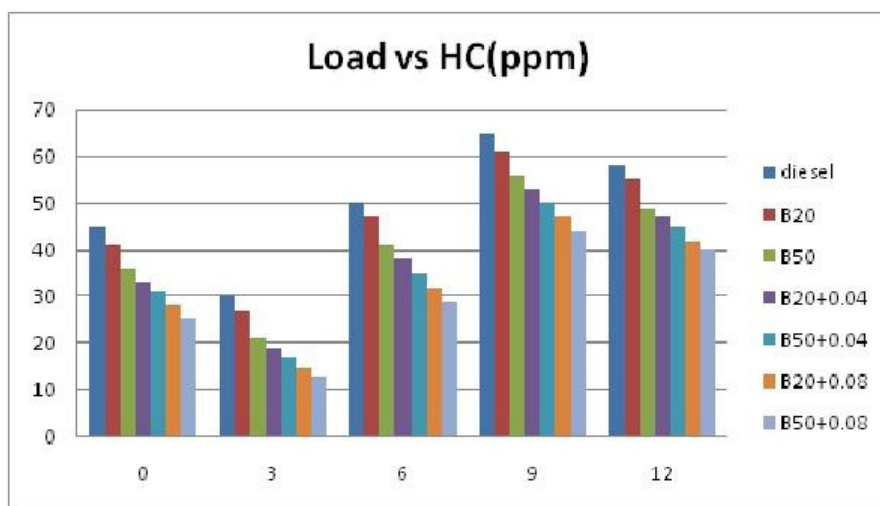


Figure 11. Load vs. HC emissions at different blends.

4.5.3 HC Emission

HC is an important parameter for determining the emission behaviour of the engines. It is observed from Figure 11 the HC emissions are decreased as compared to diesel fuel. The reason is similar to that about CO emissions.

5. Conclusion

The performance, and the emission characteristics of cotton seed oil and its all blended fuels have been done in a single-cylinder, constant speed, direct-injection diesel engine. Based on experimental data, the following conclusions have been drawn.

- The BTE of the engine increases with increasing load for diesel and biodiesel and its blends with the addition of Nano additive (Cerium Oxide (CeO_2)).
- At lighter loads specific fuel consumption is less in case of diesel-biodiesel blend with nano additive compared to that of diesel, but with an increase in load there is little variation.
- The Air-Fuel ratio of the engine decreases with increasing load for diesel and biodiesel and its blends with the addition of Nano additive (Cerium Oxide (CeO_2)).
- The EGT of the engine decreases with increasing load for diesel and biodiesel and its blends with the addition of Nano additive (Cerium Oxide (CeO_2)).
- The NO_x emissions with cotton seed oil and their different blend accepts B20 + 0.04 and B20 + 0.08 gm with addition of Nano additive decrease as compared to diesel fuel.
- CO emissions are less at lower loads for all blends compared to diesel fuel, but CO emissions are nearly equal with that of diesel fuel at higher loads.
- HC emissions are less for all the blends at all loads, compared to that of diesel fuel.

In this experimental observation the NO_x emissions of the fuel blends are higher with increase of load compared with diesel fuel emission. These emissions are reduced with various other emission controlling techniques.

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