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Study of Effect of Using Nanoadditives SiO_2 and MgO on Performance and Emission Characteristics of A CI Engine Fuelled With Diesel and WVO-Biodiesel Blend

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ABSTRACT

The nanoadditive play very important role on performance enhancement in IC engines, nanoadditive reduces emission characteristics and improves engine life as well, there are various types of nanoadditves used in IC engine like ZnO, Al_2O_3, SiO_2, CeO_2, etc. The results reveal that brake thermal efficiency at full load condition is 31.8% for B20MgO (20% Magnesium nanoadditives) fuel blend and 29.4% for B20SiO_2 (20%Silicon nanoadditives) fuel blend. Fuel consumption 0.26 kg/hr in the case of B20SiO_2 (20% Silicon nanoadditives) fuel blend and 0.2 kg/hr for B20MgO (20% Magnesium nanoadditives) fuel blend respectively whereas for the neat diesel it is 0.29 kg/hr. This is the major contribution due to the presence of the nanoparticles that leads to the complete combustion of the fuel. Moreover, carbon monoxide emission at full load condition is 0.136% by volume and 0.157% higher in the case of B20SiO_2(20% Silicon nanoadditives) respectively compared to the neat diesel. However, the presence of nanoparticle enhances the NOx emission, due to the maximum cylinder pressure and higher heat release rate achieved during the combustion process. The smoke density is minimum for B20MgO (Magnesium) at all loads and maximum for B20SiO_2 (Silicon) blends at all loads.

Keywords: D.I. Diesel engine, waste vegetable methyl ester biodiesel, B20SiO_2, B20MgO Blended fuel, Brake thermal efficiency, Injection Timing, Emissions.

1. INTRODUCTION

Global warming can be explained in terms of an increase in the earth's average surface temperature as a consequence of the increase in the concentration of greenhouse gases in the atmosphere. The primary greenhouse gases in the atmosphere such as, CO_2 and methane absorb heat radiation that usually escapesfrom the earth's surface which in turn enhances the temperature of the earth. Global warming has emerged as one of the biggest environmental issues throughout the world. According to the USEPA, the earth's average temperature has increased by 0.8°C over the past century. The most important fact is that more than half of this increase has occurred in the last 25 years. It indicates that the earth's temperature is rising at a faster rate than ever before in the past. The major human activities like fossil fuel combustion, deforestation, and industrialization emit significant pollution into the atmosphere, and hence they are regarded as crucial factors that determine the fate of global warming on the earth.

The burning of fossil fuels emits around 21.3 billion tons of CO_2 per year, however only half of the emitted CO_2 can be absorbed by the natural processes that usually taken place on the earth, and hence there is a net increase of 10.65 billion tons of atmospheric CO_2 per year. CO_2 is one of the important greenhouse gases that enhances radioactive forcing and contributes to global warming, which leads to a rise in the earth's average surface temperature and thereby induces major negative impacts.

2. EMISSION OF DIESEL ENGINE - OVERVIEW

The scientific and policy-making communities have identified that black carbon plays an important role in climatic change by heating our planet and altering precipitation patterns. Diesel engineshave been recognized as one of the major global sources of black carbon emissions. Today, the U.S. is accounted for about 5% of all black carbon emissions and is expected to contribute to only 2% of global on-road vehicle emissions by 2022. This remarkable progress is a result of new clean diesel technologies that include changes in domestic fuel composition along with advances in engine design andemissions control technology. Figure 1 shows the global black carbon emission sources.

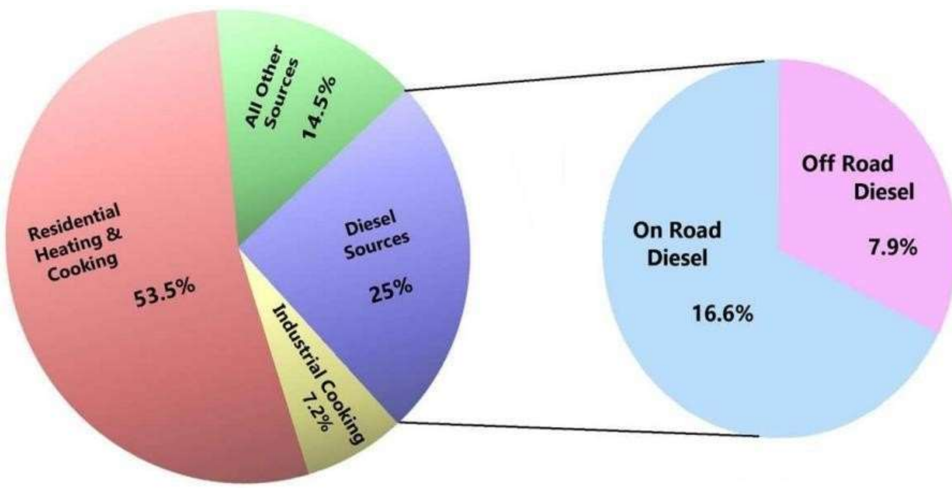

Figure-1: Global black carbon emission sources

Diesel engines have been endowed with high thermal efficiency and hence they have been widely used in automobiles. Meanwhile, Diesel engines are recognized as one of the significant contributors to the diff emissions such as HCs, particulates, NOx, and SO_2. These emissions produce very harmful effects to human beings and also to the earth's whole environment as a consequence of inducing acid rain and photochemical contamination and hence subject to strict environmental legislation. In the current era, improving the performance of diesel engines is an important challenge owing to the fast depletion of fossil fuel resources as well as harmful HC and NOx emissions. In this respect, several efforts have been made towards the reformulation of diesel fuel and thereby reduce these harmful emissions without affecting the physicochemical properties of diesel fuel such as viscosity, flash, fire point, etc. (Baumgard &Kittelson 1985; Lepperhoff & Kroon 1985; G¨ur¨u et al 2002).

3. NANO ADDITIVES

In order to overcome the problems associated with biodiesel (Pradipkumar et al 2010), the chemical substances derived from organic materials, and inorganic metals were used as fuel additives. A fuel additive generally improves combustion efficiency, and thereby reduces the pollution load. The physics should explain for provided fuel additives which improve the combustion process of fossil fuel in combustion systems. A particular use of these additives is for increasing the efficiency of the combustion and the reduction of harmful pollutants emitted from combustion systems i.e., continuous combustion systems and internal combustion systems. The Additional particular use of the present additive is in reducing the corrosive effects of combustion by-products on the combustion system. The fuel additives of the invention shorten the ignition delay of the fuel and bind to atomic oxygen resulting in reduced emissions of harmful pollutants as well as increased combustion system efficiency. The metals such as manganese, iron, copper, barium, calcium, platinum, etc. have been used as combustion catalysts for HC fuels. Recent advances in nanoscience and nanotechnology enable the production, control, and characterization of nano-scale energetic materials. The nanomaterials are more effective when compared to bulk materials because of their higher surface area. Another important advantage of nanomaterials is its size, since they can avoid the chance of clogging in fuel injector and filter which are possible as in the case of micron-sized particles.

4. EXPERIMENTAL SETUP AND METHODOLOGY

- **Test Engine**

A Schematic view of the experimental setup is shown in figure 2. A 4-stroke, single-cylinder, compression ignition engine was utilized for evaluating the performance and exhaust characteristics. Through the computerized test rig, we can measure airflow, fuel flow, temperature, and load. The suggested injection timing by the manufacturer is 230b TDC (static) and the nozzle inlet pressure of 230 bar.

Figure-2: Photographic view of the experimental setup

- **Engine Instrumentation**

The details of the engine instrumentation of the existing test setup are described below. The Airbox, fuel tank, manometer, transmitters for air, fuel measuring unit had been assembled in the panel box.

- **Dynamometer**

An electrical eddy current dynamometer was coupled to the engine. Load cell sensor was used to vary the load on an eddy current dynamometer that is coupled to the engine.

- **Speed measurement**

The speed is quantified using an electro-magnetic pick-up in conjunction with a digital indicator.

- **Fuel flow measurement**

Fuel flow rate is measured on a volume basis using a burette and stopwatch. For the measurement of the fuel flow rate of the engine, the time for a definite quantity of the fuel flow is noted. This gives the fuelflow rate for the engine.

- **Airflow measurement**

Airflow rate is measured using a manometer fitted to the panel box and connected to the airbox through tubes. Air from the atmosphere is made to flow through the orifice fitted to the airbox. The reading of themanometer for the intake of a definite quantity of air gives the airflow rate of the engine.

- **Temperature measurement**

The Temperature of the exhaust gas is measured using chromel-alumel (k-Type) thermocouples.

- **Cooling water measurement**

Rotameter was used to control the flow of water through calorimeter and interconnected water jackets around cylinder block.

- **Exhaust gas analyzer**

An exhaust gas analyzer, for estimation of the pollutants in the exhausts, is attached to the engine. This analyzer is utilized to measure three main pollutants i.e., Carbon monoxides (CO), Nitrogen oxides (NOx), and Unburnt hydrocarbons (HC).

Labview based engine performance analysis software package "Enginesoft" was provided for online performance evaluation. The engine specifications are given in Appendix A.

- **Cylinder Pressure Measurement**

Kistler piezoelectric transducer with a range of 0 to 250 bar was used. The cylinder pressure was measured with a water-cooled piezoelectric transducer.

Preparation of different types of fuels

Different types of fuels were prepared by dispersing WVO biodiesel content into the Diesel fuel. The composition and designation of the fuels for third stage of experimental work is shown in Table-1.

Type of fuel	Load (Kg)	Composition of Nanoparticle in the best biodiesel blend	Injection pressure (bar)	Designation of the fuel
1	2	20	230	$B20+SiO_2$
		20	230	B20+MgO
2	4	20	230	$B20+SiO_2$
		20	230	B20+MgO
3	6	20	230	$B20+SiO_2$
		20	230	B20+MgO
4	8	20	230	$B20+SiO_2$
		20	230	B20+MgO
5	10	20	230	$B20+SiO_2$
		20	230	B20+MgO

Table-1: Composition of fuels prepared for the third stage of experimental work

5. EXPERIMENTAL PROCEDURE

The following experimental procedure was followed during the experiment:

1. Fill the normal Diesel in the fuel tank.
2. After starting the water supply, adjust the flow rate of cooling water at 80 liters per hour (lph) to the dynamometer and for the engine at 300 lph.
3. Check all the connections before giving electric supply to the computer.
4. Click on the lab view-based "Engine soft" software package for an on-screen evaluation of the performance of the engine.
5. Run the engine.
6. Select the log option in the software and assign the fuel supply by revolving the supplied knob.
7. Enter the value of specific gravity and heating value of the fuel in the software. Then select the run option and run the engine for 15 minutes without any load.
8. After 1 minute, the display changes to input mode, then enter the values of water flows in the calorimeter and cooling jacket. Now enter the name of the file in the software and insert the probe of the gas analyzer into the exhaust at the appropriate place. Then let it for few minutes so that it could stabilize.
9. Save the reading for no-load conditions.
10. Repeat the experiment at different loads.
11. Save the readings.
12. After the completion of the experiment, remove the load from the engine and turn off the engine.
13. Shut down the computer.
14. After a few minutes, turn off the water supply.

6. RESULT AND DISCUSSION

Brake thermal efficiency

The variations of brake thermal efficiency with load for both cases are shown in figure 3 Brake thermal efficiency is defined as the ratio of brake power to product of fuel consumption and calorific value. Brake thermal efficiency for all the fuels increases as the load increase. The brake thermal efficiency increases for B20MgO (Magnesium) and is minimum for diesel as compare with others as shown in graph. Maximum efficiency obtained in 10kg load.

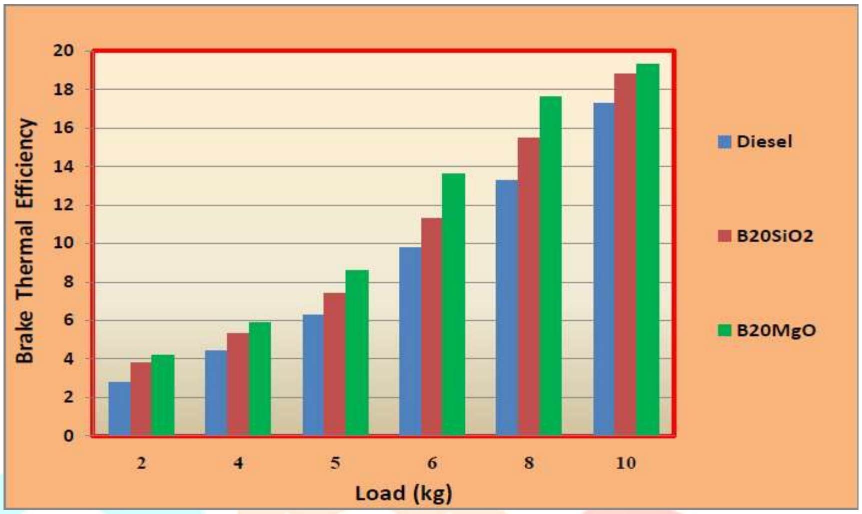

Figure-3: Variation of brake thermal efficiency with load

Fuel Consumption

Figure-4 shows fuel consumption for different loading conditions. From this graph, it is concluded that the fuel consumption is decreased with the increase of load for all fuels. Fuel consumption is lower for B20MgO (Magnesium) as compare to $B20SiO_2$ (Silicon). it seems from the result B20MgO (Magnesium) has better fuel consumption than $B20SiO_2$ (Silicon), which means B20MgO (Magnesium) has better properties than others.

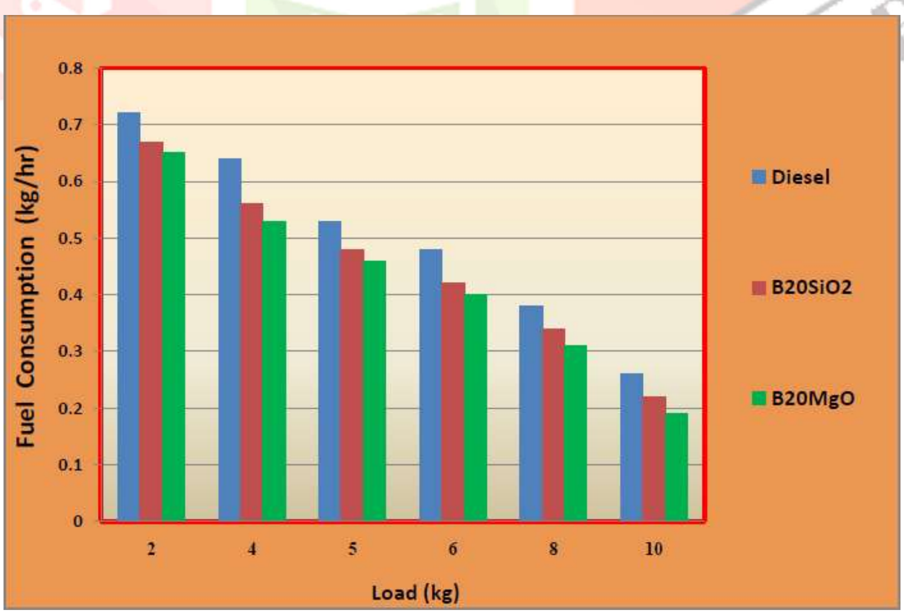

Figure-4: Variation of fuel consumption with load

Carbon Monoxide Emission

Figure-5 shows the variation of Carbon Monoxide (CO) with Load at various Oxygen admission levels. The main reason for the generation of CO emission is incomplete combustion and it is generally due to insufficient availability of oxygen. From the above graph, it is clear that the neat diesel has the highest percentage of CO emissions than other blends. The carbon monoxide emission is minimum for B20MgO (Magnesium) at all loads and maximum for B20SiO_2 (Silicon) blends at all loads.

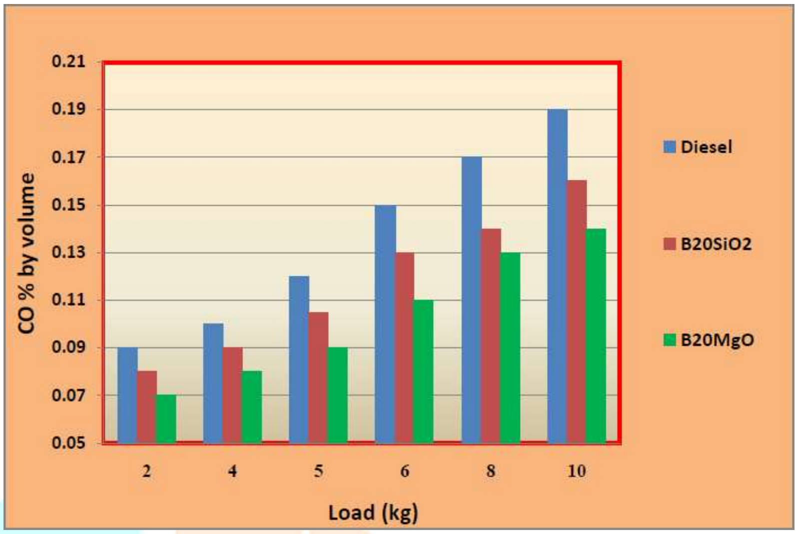

Figure-5: Variation of carbon monoxide emission with load

Hydrocarbon Emission

Figure-6 shows the variation of HC emission for different loading conditions. The hydrocarbon reacts with air to produce smog. This may reduce visibility. In a conventional internal combustion engine, the hydrocarbon fuel burns inside the engine in the presence of air. The hydrocarbon emission of B20MgO (Magnesium) blends is much lower than that of B20SiO_2 (Silicon) blends, here B20MgO (Magnesium) have minimum hydrocarbon emission for all loads and maximum in 20SiO_2 (Silicon) blends of fuel.

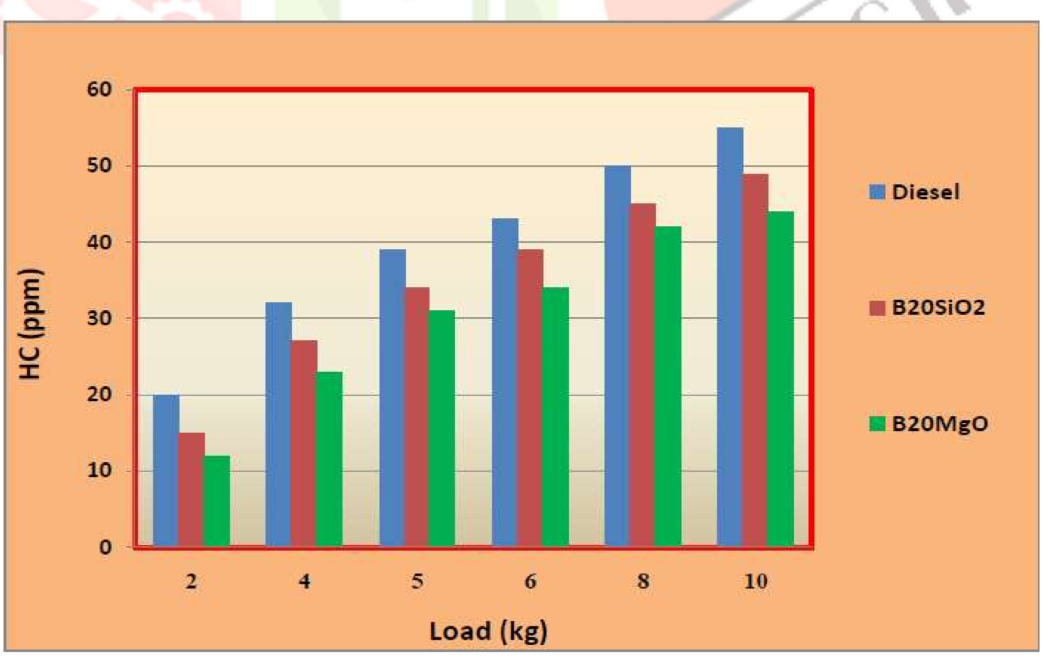

Figure-6: Variation of hydrocarbon emission with load

7. CONCLUSIONS

- Fuel consumption is very less for B20MgO (Magnesium) about 8% less, here B20MgO (Magnesium)gives lower fuel consumption than B20SiO_2 (Silicon).
- Brake thermal efficiency is high for B20MgO (Magnesium), here B20MgO (Magnesium) gives higher brake thermal efficiency than B20SiO_2 (Silicon).
- Hydrocarbon emission is very less for B20MgO (Magnesium), the result shows that the B20MgO(Magnesium) gives lower Hydrocarbon emission than B20SiO_2 (Silicon).
- Carbon monoxide emission is very less for B20MgO (Magnesium), result shows that the B20MgO(Magnesium) gives lower Carbon monoxide than B20SiO_2 (Silicon).

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