The Impact of Nanoparticle as Additive with Waste Cooking Oil Biodiesel Blends on Performance, Combustion and Emission Characteristics of Diesel Engine

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Abstract— *In spite of the recent research advancements in the field of biodiesel, further improvements in regard with obtaining enhanced engine performance and controlled emission still remains attention seeking. The technology for use of biodiesels (up to 20%) as alternative fuel in diesel engines has already been established. However, there are some disadvantages associated with the use of biodiesel fuels the use of biodiesel as it has lower heating value, higher density and higher viscosity, higher fuel consumption and higher NOx emission, which restricts its application. Improving the performance and ensuring the reduction in emission by the application nanoparticles constitutes one of the main key for safe guarding nation's economy and health. In this regard, nanoparticles become essential and crucial tools due to its high surface area to volume ratio of nanoparticle resulting in fine atomization and rapid evaporation of fuel promoting improved brake thermal efficiency. In this experimental investigation, biodiesel is obtained from waste cooking oil by acid and base catalysed transesterification with methanol when sulphuric acid and potassium hydroxide as catalyst. In the present work, the experimentation was conducted on a single cylinder DI diesel engine at a constant speed of 1500 rpm by using three different concentration of cerium oxide nanoparticles 50 ppm, 75 ppm and 100 ppm are discussed. The addition of 75 ppm cerium oxide nanoparticles to the fuel blend BTE was increased compared to diesel. Combustion parameters were improved along with lowered CO, UBHC emissions and decrease in NOx emission and smoke opacity was observed upon addition of 75 ppm cerium oxide nanoparticles compared to diesel.*

Keywords- Waste Cooking oil; Cerium oxide; Performance; Combustion; Emission

1. INTRODUCTION

The CI engines are widely used due to its reliable operation and low-cost. Due to modernisation in industries, transportation sector and life style causes depletion in fossil fuel resulting in scarcity of fossil fuels and which reflects on its cost. This circumstance has inspired to search suitable renewable alternative fuels for diesel engines. Between the numerous alternative fuels, biodiesel is considered as a most desirable fuel. At present, the researchers are continued research to produce biofuel from non-food, it has been discovered that waste cooking oil offer another promising feedstock source for biodiesel production. The use of straight waste cooking oil in CI engine is not possible due to content of Triglycerides. So, the transesterification process in which the triglycerides react with alcohol in the presence of alkali catalyst to provide biodiesel. But biodiesel is also having few drawbacks, such as higher viscosity, higher molecular weight, lower volatility and higher pour point compared with the diesel. These drawbacks cause poor atomization and lead to incomplete combustion. At present for vehicular fuels, combustion of numerous chemical nanoparticles is used to improve the quality of biodiesel fuel and diesel fuel to convene up the most wanted performance level. Nanoparticles will help out the petroleum to recover its engine combustion, performance and emission environmental standards. Nanoparticles are the chemical that are used to promote the properties of the fuel, are mixed with fuel such as diesel, biodiesel, gasoline, aviation oil etc. to improve the efficiency and fuel economy. Nanoparticles help the fuel to improve its engine performance and meeting environmental emission control standard.

Vairamuthu et al. [1] used calophyllum inophyllum methyl ester blended with ultralow sulfur diesel and mixture of cerium oxide nanoparticle (CeO2) to investigate engine performance and emissions. They observed noticeably reduced HC and NOx emission with enhanced BTE. K. Nanthagopal et al. [2] used zinc oxide and titanium dioxide nanoparticles addition in Calophyllum inophyllum biodiesel to analyse the Performance, Combustion and emission characteristics od diesel engine. In this investigation, they observed increase in brake thermal efficiency 5-17% and NOx emission was lower than pure Calophyllum inophyllum biodiesel for all CIME nano emulsions but slightly higher than conventional diesel fuel. Ramesh D K et al. [3] they carried out experimental investigation in CI engine by using poultry litter oil oil B20 biodiesel blend and B20 biodiesel blend with 30mg/l alumina nanoparticles. They observed considerable reduction in CO, UBHC & NOx emissions for with alumina nanoparticle. Chiranjeeva Rao Seela et al. [4] had examined in their study the engine's performance and emission by adding cerium oxide nanoparticle additives in diesel and Mahua Methyl Ester blends. The experimental results indicated that BTE of B20+100 ppm cerium oxide was increased by 1.8 with 1 % betterment in SFC. Emissions of HC, CO were reasonably lower than Diesel fuel. From the literature review, it is resolved that up to 20% of biodiesel with diesel fuel caused in better performance, controlled combustion and emission of diesel engine. Likewise, nanoparticles such as cerium oxide also can be blended directly to the biodiesel. Recent studies showed that the cost of the production of biodiesel can be reduced by more than half compared to virgin vegetable oils by using waste cooking oil as feedstock. In this experimental investigation, the effects on the Performance, combustion and emission characteristics of diesel engine of the addition of cerium oxide nanoparticle on waste cooking oil methyl ester were examined.

TABLE -1: ABBREVIATION AND SYMBOLS

BP	Brake Power
BTE	Brake Thermal Efficiency
HRR	Heat Release Rate
B20	20% biodiesel + 80% Diesel
WCOME	Waste cooking Oil Methyl Ester
UBHC	Unburnt Hydrocarbon
NOx	Oxides of Nitrogen
ppm	Parts per million
WCO	Waste Cooking Oil

TABLE -2: PROPERTIES OF FUELS USED FOR TESTING

Characteristic of oils				
Properties	**Diesel**	**WCO**	**WCOME**	**B20WCOME**
Kinematic Viscosity (40^0 C, Cst)	3.05	43	5.83	4.01
Heat Value (MJ/kg)	42.6	29	37.2	39.2
Density (Kg/m^{3})	828	914	874	826
Flash Point ^{0}C	60	307	150	98
Cetane number	40	53	51.48	51.48

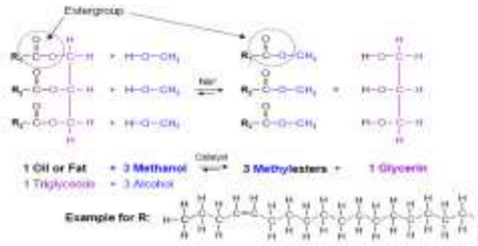

Fig-1 Schematic representation of Transesterification

2. METHODOLOGY
Experimental details

1.Production of biodiesel from WCO

The raw waste cooking oil was collected from the restaurant, hostels and fast food centres and the biodiesel was prepared by transesterification process (Fig.1). The transesterification process of the waste cooking oil is conducted in the biodiesel reactor in the presence of potassium hydroxide and methyl alcohol to produce the waste cooking oil esters generally known as waste cooking oil biodiesel (WCO) or waste cooking oil methyl ester (WCOME).

2. Determination of Fuel properties

The properties of Diesel, collected raw waste cooking oil, waste cooking oil methyl esters and B20 were determined and tested to meet to meet the ASTM standard requirement. The required fuel properties of biodiesel blends are listed in Table 1.

3. Preparation of nanofluids

In the present experimental investigation cerium oxide is used as a nanoparticle additive. The morphology of CeO_2 were examined utilizing SEM. The nano liquids are set up for three diverse grouping of 80 ppm, 100 ppm and 120 ppm. The ultrasonicator helps in compelling and uniform scattering of nanoparticles in biodiesel.

4. Experimental Details

In this investigation the fuel used was petroleum diesel and WCOME blends with and without cerium oxide. The metal based additive was cerium oxide (CeO_2). The computerized four stroke, single cylinder, water cooled, 3.5 kw at constant speed static diesel engine was selected for experimentation. The selected engine was empowered with required instrumentation and i3sys gas analyser and i3sys smoke meter EDM 1601 was used for measuring amount of smoke emitted. The engine test was carried out by maintaining injection timing of 23 degrees BTDC, engine constant speed of 1500 rpm and compression ratio of 17.5:1. In the present study, the engine run were conducted at no load, 25% full load, 50% of load, 75% of full load and full load conditions. The engine specification is shown in Table.

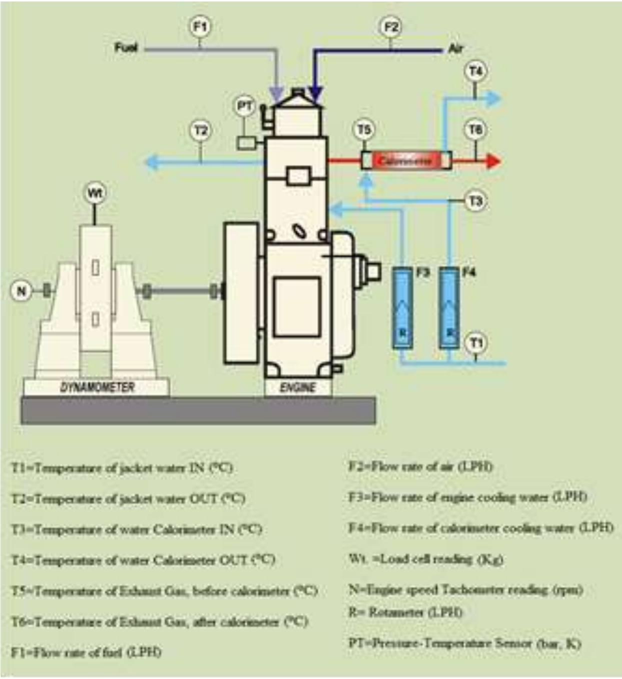

Fig-2 Schematic representation of the experimental setup

Table-3 Engine and Dynamometer Specification

Four Stroke Single Cylinder Diesel Engine Test Rig	
Make	Kirloskar
Capacity	3.5KW
Compression ratio	17.5:1
Cylinder bore	80mm
Stroke	110mm
Cylinder capacity	661cc
Cooling	Water cooling
Loading	Eddy current Dynamometer
Speed	1500rpm

Table-4 Uncertainties Percentage

Parameters	Average uncertainties
Air flow rate	1.2%
LCV of fuel	1.0%
Engine speed	1.3%
Gas flow rate	2.1%
Engine load	0.2%
Liquid fuel flow rate	0.15%
Temperature	1.0%
Cylinder pressure	0.8%

3. RESULTS AND DISCUSSION

3.1. Performance Parameter

3.1.1 Break thermal efficiency

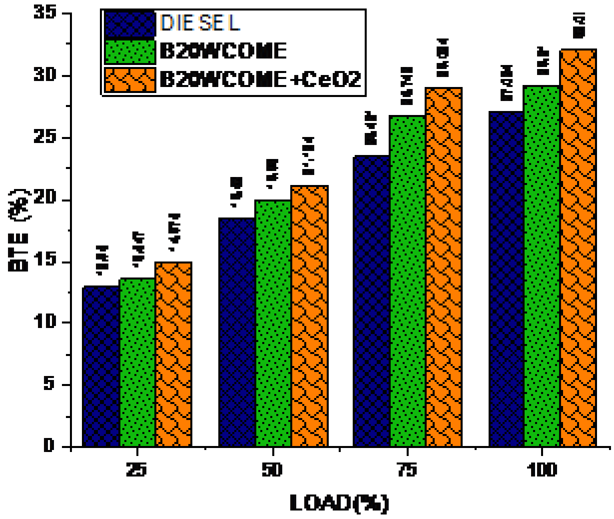

Fig-3: Variation of BTE with load

The variation of BTE with respect to load is shown in Figure 3. Due to reduction in heat loss (increase in power with increase in load), for all the tested fuels BTE improved with respect load. B20WCOME CeO_2 shows the better BTE than the Diesel and B20WCOME due to high surface area to volume ratio of nanoparticles resulting in fine atomization and rapid evaporation of fuel promoting improved BTE.

3.2. *Combustion Analysis*

3.2.1. Heat Release Rate

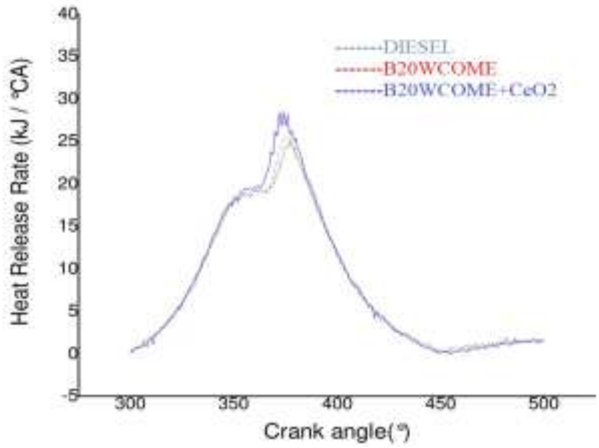

Fig-4: Variation of HRR with Crank angle

The variation of Heat Release Rate with several crank angle for all the tested fuels is shown in Figure 4. Due to more oxygen molecules present in the molecular structure B20WCOME and B20WCOMECeO_2 shows a marginal increase in HRR compared to diesel. But, the B20WCOMECeO_2 shows the lower heat release rate than the B20WCOME due to advancement of combustion phase by improved atomization.

3.3. Emission Analysis

3.3.1. Oxides of nitrogen

From the Figure 5 it is observed that the NOx increases with respect to load for all tested fuels, this is due to increase in load, when there is a increase in load there is a increase in combustion chamber temperature and the NOx is temperature dependant phenomena. But at maximum load B20WCOME CeO2 shows the marginal reduction in NOx dur to cerium oxide nanoparticles. Here cerium oxide nanoparticles promote better homogeneity and increases the reactivity of the fuel blend by increasing the surface area and reduction in ignition delay.

Figure 6 shows the variation of CO with respect to the load. It is observed that the presence of biodiesel always leads to reduction of CO emission due to more oxygen content in the biodiesel. Addition of cerium oxide nanoparticle leads to further reduction in CO at higher load, this is due to complete combustion of fuel, better atomization and system higher temperatures because of additional surface energy by cerium oxide nanoparticles.

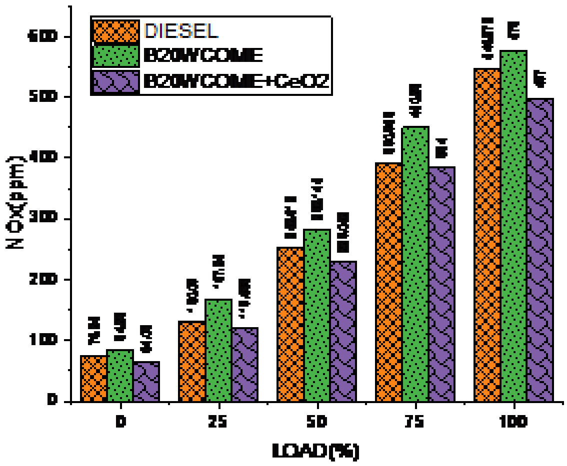

Fig-5: Variation of NOx with load

3.3.2. Carbon monoxide

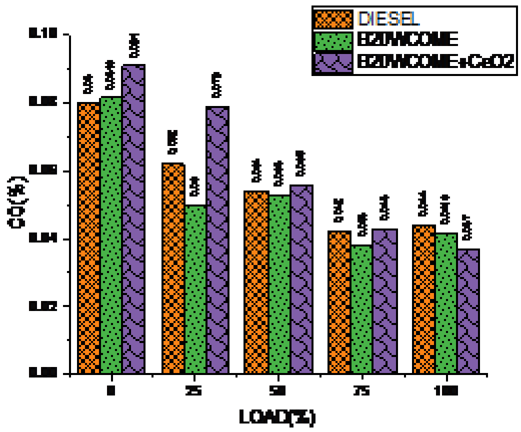

Fig-6: Variation of CO with load

3.3.3. Unburned hydrocarbon

From Figure 7 it is clear that UBHC emission for all the blends are lower than the diesel, this is due to oxygen content present in the biodiesel leads to complete combustion. Marginal reduction in UBHC emission when cerium oxide nanoparticles were added to B20WCOME due to the catalytic behaviour of cerium oxide nanoparticles.

Figure 8 shows the variation of smoke opacity with load. The smoke opacity of the exhaust gas increase with load for all the tested fuels, this is due to more amount of fuel being consumed at full load, So the soot formation is more. It is noticed that, smoke opacity for the blends is higher than the diesel, due to poor volatility and higher viscosity of the blend.

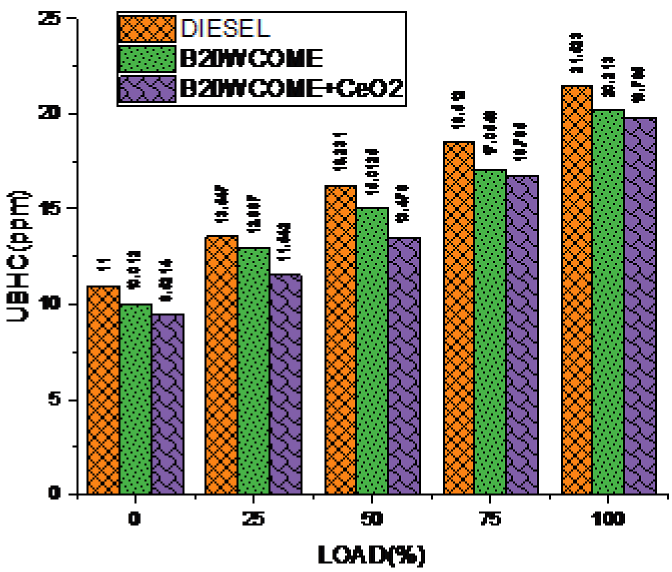

Fig-7: Variation of UBHC with load

3.3.3. Smoke Opacity

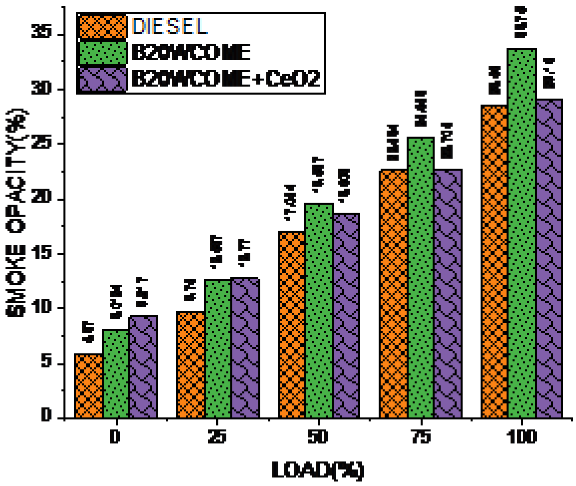

Fig-8: Variation of UBHC with load

4. CONCLUSION

The present investigation was conducted with the blends of B20WCOME, B20WCOMECeO$_2$ for zero to maximum load condition and the results were studied in comparison with diesel fuel. All the tests were conducted at above mentioned engine specification and parameters. Reduction in density and kinematic viscosity by transesterification of the waste cooking oil.

- The B20WCOME+CeO2 showed increased BTE with respect to Diesel and B20WEOME
- The HRR was found to maximum for B20WCOME+CeO2.
- The NOx emission drastically reduced for the B20WCOME+CeO2 when compared with diesel due to the combined effect of Cerium Oxide nanoparticles.
- For B20WCOME+CeO2 the emission of HC, CO decreases as compared to diesel signifying a near complete and an efficient combustion.

Thus, these factors strongly support the fact that B20WCOME+CeO2 can be a promising fuel for diesel engines in future as they have good efficiency and reduced emissions.

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