Investigation on effect of nanoparticle additives in biodiesel on CI engine

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***Abstract*—.** *Diesel engine plays a vital role in power generation, transportation and industrial activities. The main advantages of the diesel engine over the gasoline spark ignition engine include its durability, reduced fuel consumption and lower emission of carbon monoxide and unburned hydrocarbon. Due to higher efficiency, diesel engines are of high interest in light duty vehicles. The objective of the present study is to investigate the effect of cerium oxide nanoparticles blended diesel fuel combustion, performance and exhaust emission characteristics of a diesel engine. Experiments were conducted to determine engine performance and emissions parameters in a single cylinder diesel engine using diesel, B5, B10, B15, B5C (500ppm) and B15C (750ppm). The B5C and B15C fuel blended cerium oxide nanoparticles in mass fractions of 500ppm and 750ppm, respectively with the help of a ultrasonicator. After a series of experiments, it was observed that 500ppm of cerium oxide nanoparticles blended fuel exhibits a significant reduction in specific fuel consumption and hydrocarbon emissions at all operating loads compared to other cases. There is a considerable reduction in carbon monoxide and smoke emissions. Due to complete combustion NOx emissions increases. The results also showed a considerable enhancement in brake thermal efficiency due to the influence of cerium oxide nanoparticles addition in diesel blend. As the dosage level of cerium oxide nanoparticles increases to 750ppm the brake thermal efficiency, HC, CO and NOx emissions decreases considerably with respect to 500ppm of cerium oxide nanoparticles blend. There is a noticeable increase in specific fuel consumption and smoke emissions of B15C with respect to B5C.*

***Keywords*— ceo2 nanoparticles, biodiesel, diesel engine, transesterification, emissions**

I. INTRODUCTION

The whole world is facing the crises of depletion of fossil fuels as well as the problem of environmental degradation. The rapid depletion of fossil fuel reserves with increasing demand and uncertainty in their supply, as well as the rapid rise in petroleum prices, has stimulated the search for other alternatives to fossil fuels. In view of this, there is an urgent need to explore new alternatives, which are likely to reduce our dependency on oil imports as well as can help in protecting the environment for sustainable development. Many alternative fuels are being recently explored as potential alternatives for the present high-pollutant diesel fuel derived from diminishing commercial resources.

Biodiesel emerges as one of the most energy-efficient environmentally friendly options in recent times to full fill the future energy needs. Biodiesel is a renewable diesel substitute that can be obtained by combining chemically any natural oil or fat with alcohol. During the last 15 years, biodiesel has progressed from the research stage to a large scale production in many developing countries. In Indian context, non-edible oils are emerging as a preferred feedstock and several field trials have also been made for the production of biodiesel

Vegetable oils either from seasonal plant crops or from perennial forest tree's origin, after being formulated, have been found suitable for utilization in diesel engines. Many traditional oil seeds like Pongamia, Glabra, Jatropha, Mallous philippines, Garcinia Indica, Thumba, Karanja and Madhuca indica etc. are available in our country in abundance, which can be exploited for biodiesel production purpose. Many vegetable oils, animal fats and recycled cooking greases can also be transformed into biodiesel. Biodiesel can be used neat or as a diesel additive in compression ignition engines.

In this chapter, a detailed survey of available literature is therefore undertaken to review the different research achievements on vegetable oils and biodiesel as an alternative fuel for a compression ignition engine, problems associated with pure vegetable oils and their possible solutions with their structural details have been looked into. In addition to this, physical and chemical properties of vegetable oils as well as biodiesel, fuel formulation techniques, biodiesel production and utilization, engine combustion, performance and emission characteristics have also been collected. Efforts have also been made to assess the economic viability of biodiesel

II. LITERATURE REVIEW

Wong (1977) studied various mixtures of methane and carbon dioxide as fuels in an internal combustion (IC) single cylinder, four-stroke gasoline engine. The engine was modified for fueling gaseous fuel. Brake horsepower, brake specific fuel consumption, concentrations of unburned hydrocarbon, nitric oxide and carbon monoxide were measured based on fuel quality. At the same engine speed (RPM), as the fuel quality lowered (the fraction of carbon dioxide increased), brake horsepower decreased while brake specific fuel consumption increased. When the fuel quality was lowered, unburned hydrocarbon and carbon monoxide emissions were increased. However, lowering the fuel quality tended to reduce nitric oxide emission.

Hossain and Boyce (2009) have studied optimum conditions of alkaline-catalyzed transesterification process for biodiesel production from pure sunflower cooking oil (PSCO) and waste sunflower cooking oil (WSCO) through transesterification process using alkaline catalysts. By taking some important variables such as volumetric ratio, types of reactants and catalytic activities were selected and approximately 99.5% biodiesel yield acquired under optimum conditions of 1:6 volumetric oil-to-methanol ratio, 1% KOH catalyst at 40ºC reaction temperature and 320 rpm stirring speed. Result showed that the biodiesel production from PSCO and WSCO exhibited no considerable differences. The research demonstrated that biodiesel obtained under optimum conditions from PSCO & WSCO was of good quality and could be used as a diesel fuel which considered as renewable energy and environmental recycling process from waste oil after frying.

Thirumarimurugan et al. (1988) Sivakumar, Xavier, Prabhakaran and Kannadasan have conducted experiments to convert waste sunflower oil used for domestic purposes such as cooking oil into biodiesel using an alkali catalyzed transesterification process. Their article reports experimental data on the production of fatty acid methyl esters from sunflower oil using sodium hydroxide as alkaline catalyst. The variables affecting the yield and characteristics of the biodiesel produced from these vegetable oils were studied. The variables investigated were reaction time (1–3 h), catalyst concentration (0.5–1.5 w/wt%), and oil-to-methanol molar ratio (1:3–1:9). From the obtained results, the best yield percentage was obtained using a methanol/oil molar ratio of 6:1, sodium hydroxide as catalyst (1%) and 60 ± 1 °C temperature for 1 hour to 3 hours. From the results it was clear that the produced biodiesel fuel was within the recommended standards of biodiesel fuel.

Khine1 and Tun (2013) did a feasibility study on the production of biodiesel from sunflower oil by the alkali-catalyzed transesterification method was done. The physicochemical properties of sunflower oil were firstly evaluated. Reaction parameters such as the reaction time, the amount of catalyst, the volume ratio of alcohol to oil, temperature and rate of mixing were found to significantly influence the yield and viscosity of biodiesel. The optimum conversions of sunflower methyl ester (SFME) from sunflower oil (SFO) were achieved by using NaOH catalyst 0.5 % w/v, methanol to oil volume ratio 0.25, reaction temperature 60 ºC, rate of mixing 600 rpm for a period of 3 hours. The fuel properties of SFME produced under the optimum condition agreed with all prescribed ASTM international biodiesel specification. GC-MS revealed that methyl linoleate, methyl oleate, methyl palmitate and methyl stearate were major components of SFME. The engine performance tests on prepared biodiesel revealed that it can be substituted in some part of petroleum diesel.

Nadir Yilmaz, et al. (2016) Erol Ileri, Alpaslan Atmanlı, Deniz Karaoglan, Sureyya Kocak have evaluated the suitability of hazelnut oil methyl ester (HOME) for engine performance and exhaust emissions responses of a turbocharged direct injection (TDI) diesel engine. HOME was tested at full load with various engine speeds by changing fuel injection timing (12, 15, and 18 deg CA) in a TDI diesel engine. Response surface methodology (RSM) and least-squares support vector machine (LSSVM) were used for modeling the relations between the engine performance and exhaust emission parameters, which are the measured responses and factors such as fuel injection timing (t) and engine speed (n) parameters as the controllable input variables. For this purpose, RSM and LSSVM models from experimental results were constructed for each response, namely, brake power, brake-specific fuel consumption (BSFC), brake thermal efficiency (BTE), exhaust gas temperature (EGT), oxides of nitrogen (NOx), carbon dioxide (CO2), carbon monoxide (CO), and smoke opacity (N), which are affected by the factors t and n. The results of RSM and LSSVM were compared with the observed experimental results. These results showed that RSM and LSSVM were effective modelling methods with high accuracy for these types of cases. Also, the prediction performance of LSSVM was slightly better than that of RSM.

Prabu (2017) carried out experimental investigation the performance, combustion and emission characteristics of a single cylinder direct injection (DI) diesel engine with three fuel series: biodiesel–diesel (B20), biodiesel–diesel–nanoparticles (B20A30C30) and biodiesel–nanoparticles (B100A30C30). The nanoparticles such as Alumina (Al2O3) and Cerium oxide (CeO2) of each 30 ppm are mixed with the fuel blends by means of an ultrasonicator, to attain uniform suspension. Owing to the higher surface area/volume ratio characteristics of nanoparticles, the degree of mixing and chemical reactivity is enhanced during the combustion, attaining better performance, combustion and emission attributes of the diesel engine. The brake thermal efficiency of the engine for the nanoparticles dispersed test fuel (B20A30C30) significantly improved by 12%, succeeded by 30% reduction in NO emission, 60% reduction in carbon monoxide emission, 44% reduction in hydrocarbon emission and 38% reduction in smoke emission, compared to that of B100.

Jayanthi and Srinivasa Rao (2016) investigated the use of copper oxide for Linseed oil-based biodiesel. The metal-based additive was added to biodiesel at a dosage of 40 μmol/L, 80 μmol/L and 120 μmol/L with the aid of an ultra sonicator. Experiments were conducted to study the effect of copper oxide added to biodiesel on performance and emission characteristics of a direct injection diesel engine operated at a constant speed of 1500 rpm at different operating conditions. Results show that maximum increase in brake thermal efficiency was found to be B20+ 80 PPM CuO and reduces specific fuel consumption at full load conditions. The copper oxide additive is effective in control of hydrocarbon (HC), carbon monoxide (CO), smoke and oxides of nitrogen (NOx) at full load conditions.

Arul Mozhi Selvan, et al. (2015) Anand and Udayakumar carried out an experimental investigation to establish the performance and emission characteristics of a compression ignition engine while using cerium oxide nanoparticles as additive in neat diesel and diesel-biodiesel-ethanol blends. In the first phase of the experiments, stability of neat diesel and diesel-biodiesel-ethanol fuel blends with the addition of cerium oxide nanoparticles are analyzed. After series of experiments, it is found that the blends subjected to high speed blending followed by ultrasonic bath stabilization improves the stability. The phase separation between diesel and ethanol is prevented using vegetable methyl ester (Biodiesel) prepared from the castor oil through transesterification process. In the second phase, performance characteristics are studied using the stable fuel blends in a single cylinder four stroke computerized variable ompression ratio engine coupled with an eddy current dynamometer and a data acquisition system. The cerium oxide acts as an oxygen donating catalyst and provides oxygen for the oxidation of CO or absorbs oxygen for the reduction of NOx. The activation energy of cerium oxide acts to burn off carbon deposits within the engine cylinder at the wall temperature and prevents the deposition of non-polar compounds on the cylinder wall results reduction in HC emissions. The tests revealed that cerium oxide nanoparticles can be used as additive in diesel and diesel-biodiesel-ethanol blend to improve complete combustion of the fuel and reduce the exhaust emissions significantly.

Sajith, Sobhan, and Peterson conducted experimental investigations on the influence of the addition of cerium oxide in the nanoparticle form on the major physicochemical properties and the performance of biodiesel. The physicochemical properties of the base fuel and the modified fuel formed by dispersing the catalyst nanoparticles by ultrasonic agitation are measured using ASTM standard test methods. The effects of the additive nanoparticles on the individual fuel properties, the engine performance, and emissions are studied, and the dosing level of the additive is optimized. Comparisons of the performance of the fuel with and without the additive are also presented. The flash point and the viscosity of biodiesel were found to increase with the inclusion of the cerium oxide nanoparticles. The emission levels of hydrocarbon and NOx are appreciably reduced with the addition of cerium oxide nanoparticles.

III. EXPERIMENTAL WORK

A. *Procedure of Making Biodiesel*

• Take 500ml sunflower oil (obtained from the local grocery store) in a beaker and heat it up to 60-650C.

• While heating the oil, prepare a catalyst solution with 100 ml Methanol and 3.5 grams of Potassium hydroxide flakes.

• Mix the catalyst solution by using a Magnetic stirrer.

• Take the oil out of the heater and keep it at rest for about 10-15 seconds and after that add the Catalyst solution to the warm oil.

• Keep the oil & catalyst solution mixture on magnetic stirrer for about 10-15 min.

• Take the Solution from the stirrer and keep it to rest for 24 hours.

• Biodiesel is formed after 24 hours along with the residual glycerin.

• The glycerin will be settled down under the layer of formed biodiesel.

• Separate the biodiesel and glycerin.

Table.1 Materials for Transesterification

Material / Compound	Quantity
Jatropa oil	500 ml
Methanol	100ml
Potassium Hydroxide (KOH)	3.5 gms

Fig 1. Transesterification

B. Blending of Biodiesel

Table.2 Proportions for Biodiesel Blends

Blends	Biodiesel	Diesel
B5	5%	95%
B10	10%	90%
B15	15%	85%
B100	100%	0%

Fig 2. Blends of Biodiesel

C. Determining the properties of biodiesel blends

a) Flash & Fire point

Table3. Flash & Fire points of Biodiesel

Blends	**Flash Point (°C)**	**Fire Point(°C)**
B5	60	69
B10	60	70
B15	60	70
B100	175	180
B5C	59	75
B15C	60	75

Fig 3. Pensky-Marten's Apparatus

b) Kinematic, Dynamic Viscosities & Calorific Value Measurement

Table 4. Calculated Properties of Biodiesel Blends

Type of Blend	**Redwood number (n)**	**Kinematic viscosity (η) CSt**	**Dynamic viscosity (μ) N-Sec/m2**	**Calorific value (CV) j/gm**	**Density (ρ) kg/m3**
B100	10.477	11.809	10538.55	37413	892
B05	6.975	6.653	5409.61	44270	813
B10	7.054	6.789	5534.47	43909	815
B15	7.077	6.925	5628.83	43548	820
B05N	6.739	7.005	5412.44	50542	772
B15C	6.9954	6.835	5468.22	49613	800

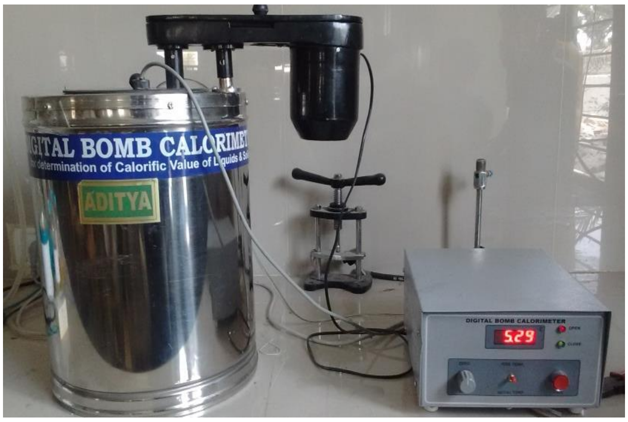

Fig 4. Bomb Calorimeter

Fig 5. Redwood Viscometer No.1

c))Carbon residue (Conradson) test

Table 5. Values of Carbon Residue

Type of fuel	Crucible weight(w1)	Crucible with oil weight (w2)	Carbon Residue (w3)	Percentage (%)
B100	13.54	15.01	13.88	23.12
B05	33.08	34.44	33.10	1.4
B10	13.54	15.05	13.60	3.9
B15	13.54	15.02	13.62	5.4
B05C(500ppm)	32.99	35.73	33.01	0.72
B15C(750ppm)	32.98	33.71	33	2.73

Figure 6. Carbon residue(Conradson) apparatus

D. Mixing nanoparticles with biodiesel blends(B5 & B10)

Table 6. Proportions Mixing Biodiesel blends with Nano Particles

Blends	**Quantity of Blends in ml**	**CeO2 quantity in mg**	**Time for ultra-sonication**	**PPM mg/lt**
B5	800	400	480sec *4 = 32min	500
B10	800	600	480sec*4 = 32 min	750

Fig 7. Mixture of CeO_2 & Bio Diesel Blends in Water Bath of Ultra Sonicator

IV. Results & Discussions

a) Efficiencies

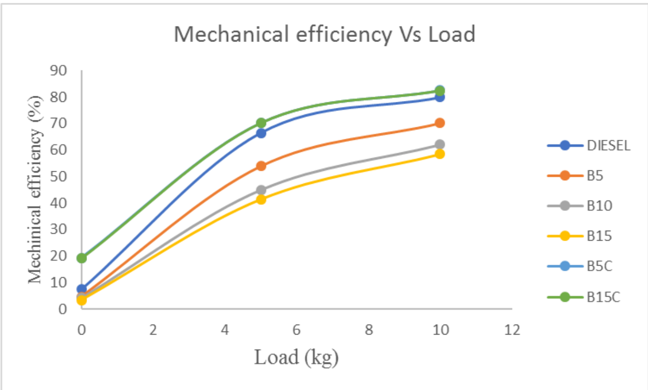

Fig 8. Mechanical Efficiency vs Load of all Fuels Used for CR 23.12:1

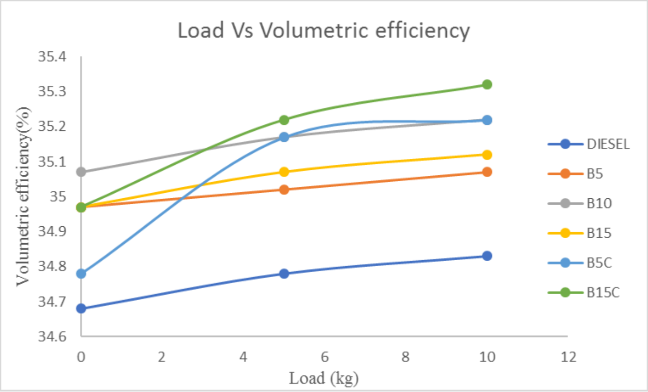

Fig 9. Volumetric Efficiency vs Load of all Fuels Used for CR 23.12:1

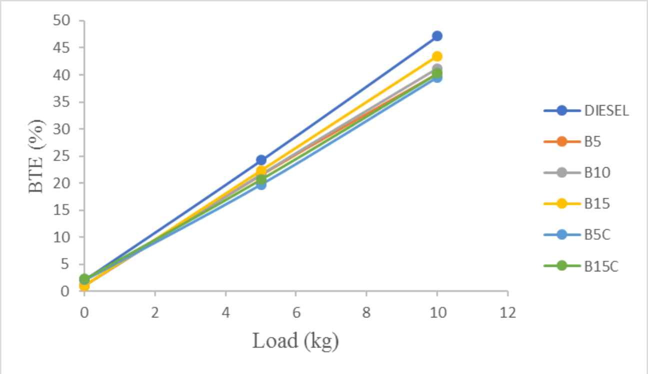

Fig 10. Brake Thermal Efficiency vs Load of all Fuels Used for CR 23.12:1

b) Emissions

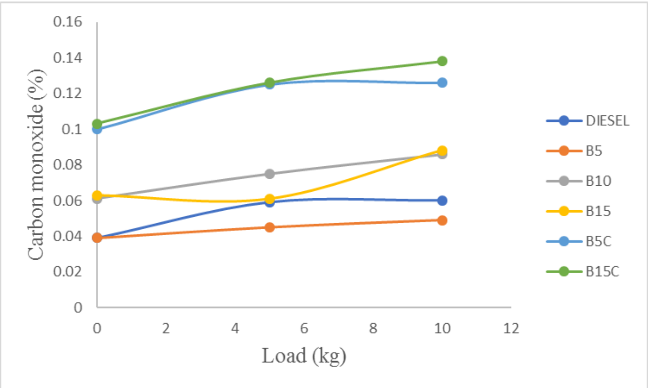

Figure11. Carbon Monoxide vs Load at CR 23.12:1

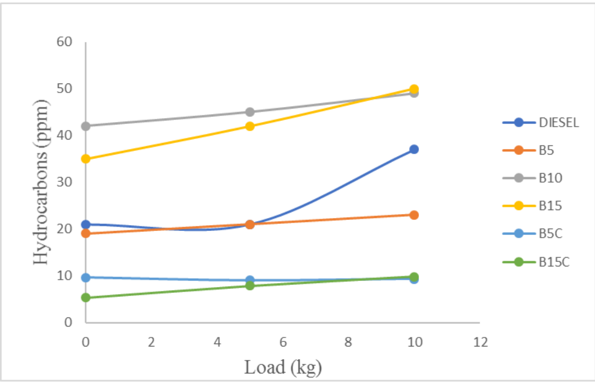

Figure12. Hydro Carbons vs Load at CR 23.12:1

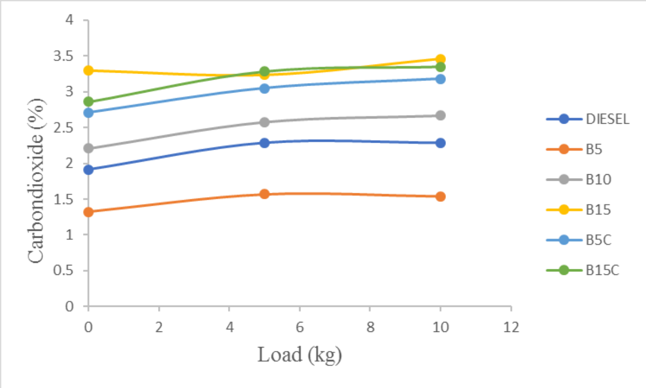

Figure13. Carbon Dioxide vs Load at CR 23.12:1

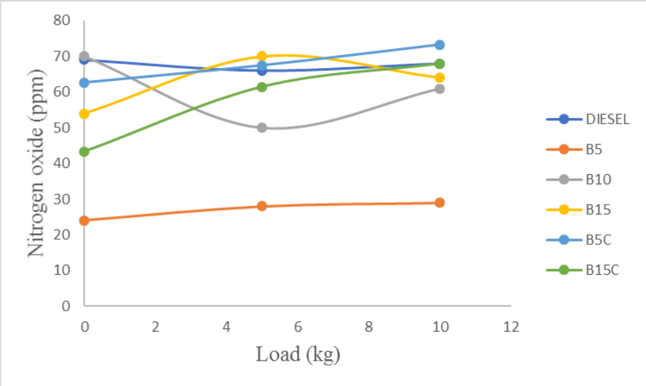

Figure14. Nitrogen Oxide vs Load at CR 23.12:1

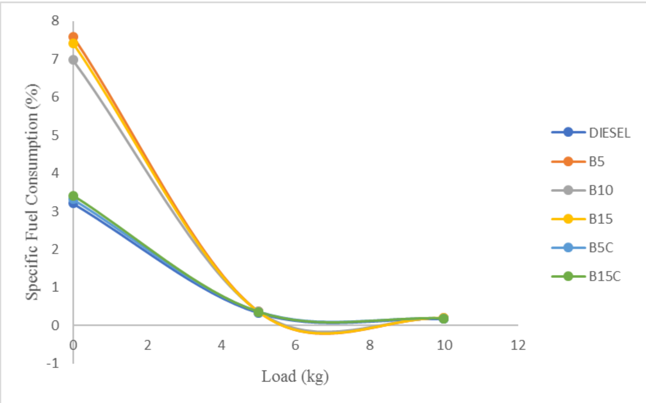

Figure 15. load Vs SFC at 23.12:1 Compression Ratio

V. CONCLUSIONS

Karanja methyl ester blended with nano particles seems to have a potential to use as alternative fuel in diesel engines.

Blending with diesel decreases the viscosity considerably. The following results are made from the experimental study-

• The brake thermal efficiency of the engine with B5C (500ppm) and B15C (750ppm) blend was marginally better than with neat diesel fuel.

• Brake specific energy consumption is lower for Karanja methyl ester-diesel blends than diesel at all loading.

• The mechanical efficiency achieved with B5C (500ppm) and B15C (750ppm) is higher than diesel at lower loading conditions. At higher loads, the mechanical efficiency of certain blends is almost equal to that of diesel.

• The emission characteristics are higher than pure diesel but the B5C (500ppm) and B15C (750ppm) has relatively better performance with respect to other blends.
• B5C (500ppm) and B15C (750ppm) can be accepted as a suitable fuel for use in standard diesel engines and further studies can be done with certain additives to improve the emission characteristics. 7)Usage of Bio – Diesel & Nano Particle Blends resulted in lower amounts of Hydrocarbons when compared to Diesel and hence by evaluating various blend compositions we can attain a proper Bio – Diesel blend which results in lower emissions and better performance.

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