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PERFORMANCE CHARACTERISTICS OF DIESEL ENGINE FUELED WITH SUNFLOWER OIL METHYL ESTER AND CEO2 NANOPARTICLES

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ABSTRACT

Previous studies with biodiesel have demonstrated that diesel engines fueled with biodiesel can reduce CO, CO2, and hydrocarbon (HC), but slightly increase BSFC because of its lower heating value, while the torque and power output for biodiesel were almost the same when compared to those of diesel fuel. This work provides an overview on the most common way to produce biodiesel i.e., Transesterification of the oils (Sunflower) with an alcohol (Methanol) in the presence of an alkaline catalyst (KOH). An additive called CeO2 nanoparticle has also been used in conjunction with biodiesel which will be helpful for reducing the emissions and improving the fuel properties. Properties like density, specific gravity, viscosity, calorific values, carbon residue, flash & fire points are determined for the blends of biodiesel. Performance characteristics and emissions of all the blends with & without nanoparticles are compared, and the results are discussed.

Keywords: *ceo2 nanoparticles, biodiesel, diesel engine, transesterification, emissions.*

I. INTRODUCTION

The biodiesel manufacturing process converts oils and fats into chemicals called long-chain mono alkyl esters, or biodiesel. These chemicals are also referred to as fatty acid methyl esters (FAME), and the process is referred to as esterification. Fig. 1 provides a diagram of the esterification process. Roughly speaking, 100 pounds of oil or fat are reacted with 10 pounds of a short-chain alcohol (usually methanol) in the presence of a catalyst (usually sodium hydroxide or potassium hydroxide) to form 100 pounds of biodiesel and 10 pounds of glycerin (or glycerol). Glycerin is a sugar and is a co-product of the biodiesel process.

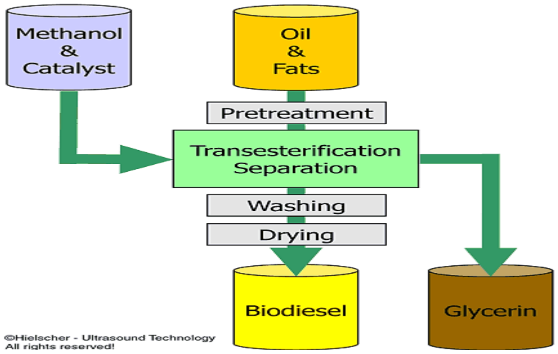

Figure. 1 Process of making biodiesel

Cerium oxide can catalyze combustion reactions, by donating oxygen atoms from its lattice structure. This catalytic activity is dependent on surface area, amongst other things, so using nanoparticles can offer distinct advantages over bulk material or larger Particles. Adding cerium oxide nanoparticles to fuel can help decomposition of unburnt hydrocarbons and soot, reducing the amount of these pollutants emitted in the exhaust and reducing the amount of fuel used. It has also been shown that cerium oxide decreases the pressure in the combustion chamber, which reduces the production of NOx and makes combustion reactions more efficient.

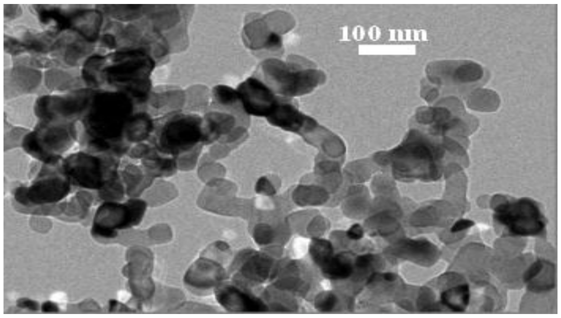

Figure 2. Nano Structure of Cerium Oxide

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 ultrasonicator. 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 compression 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.

II. 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 60-65^{0}C.
- 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
Sunflower oil	500 ml
Methanol	100ml
Potassium Hydroxide (KOH)	3.5 gms

B. Determining the properties of biodiesel blends

a) Flash & Fire point

Fig 4. Pensky-Marten's Apparatus

Table3. Flash & Fire points of Biodiesel

Blends	Flash Point	Fire Point
B5	68	82
B10	72	86
B15	76	89.5
B100	170	180

b) Kinematic and Dynamic Viscosities Measurement

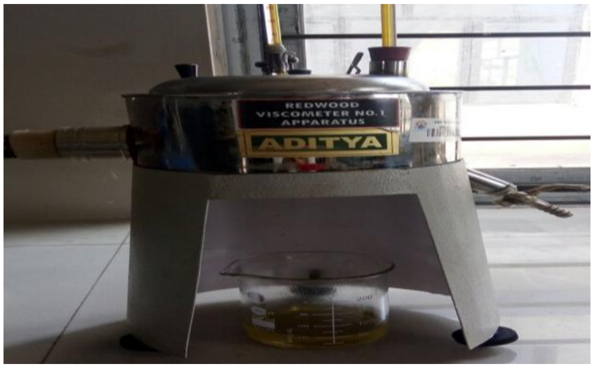

Fig 5. Redwood Viscometer No.1

Table 4. Calculated Properties of biodiesel Blends

Blends	Temperature (T) in ^{0}C	(η) in CSt	(μ) in N-Sec/m2	(ρ) in kg/m3
B100	50	9.143	7939.78	868.4
	60	7.840	6808.25	
B5	50	5.787	4655.06	804.4
	60	5.689	4576.23	
B10	50	5.478	4448.13	812
	60	4.423	3591.47	
B15	50	4.510	3667.53	813.2
	60	3.198	2600.61	

Figure 6. Bomb Calorimeter

Table5. Calculated calorific values of blends

Bio-Diesel Blends	Calorific value (C.V) in j/gm			Avg CV
	C1	C2	C3	
B5	49741	46425	34819	43662
B10	48451	44135	35819	42801
B15	46425	41451	36477	41451

Mixing nanoparticles with biodiesel blends (B5 & B10)

Table 6. Proportions Mixing Biodiesel blends with Nano Particles

Blends	Quantity ofBlends in ml	CeO_2 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 CeO2& Bio Diesel Blends in Water Bath of Ultrasonicator

III. RESULTS & DISCUSSIONS

Efficiencies

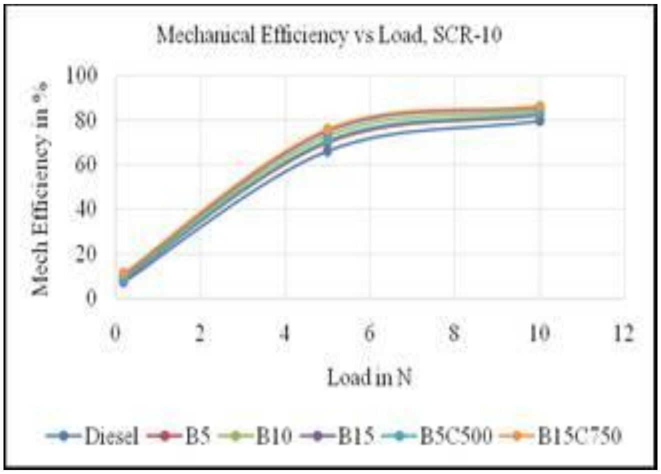

Fig 8. Mechanical Efficiency vs Load of all Fuels Used for SCR-10

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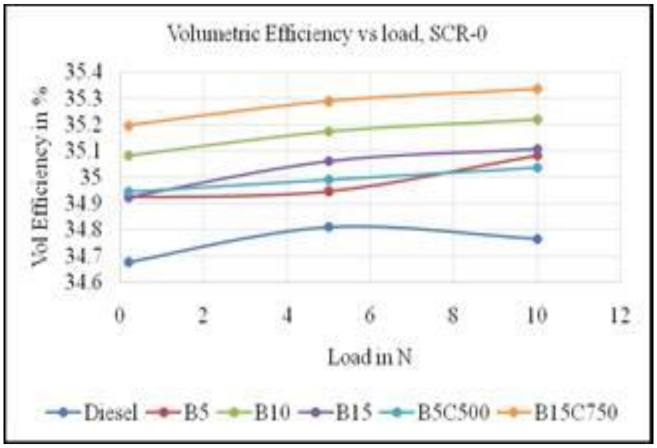

Fig 9. Volumetric Efficiency vs Load of all Fuels Used for SCR-0

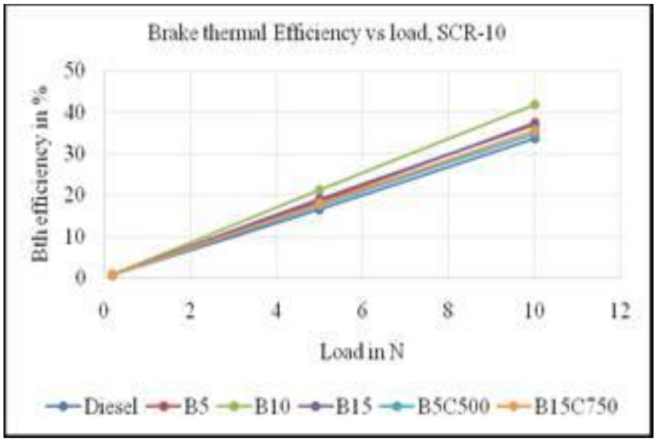

Fig 10. Brake Thermal Efficiency vs Load of all Fuels Used for SCR-10

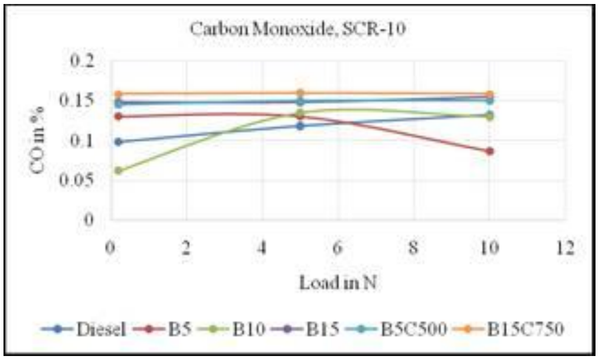

Figure11. Carbon Monoxide vs Load at SCR-10

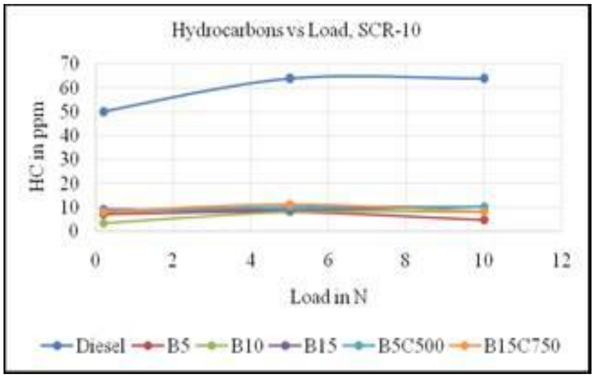

Figure12. Hydro Carbons vs Load at SCR-10

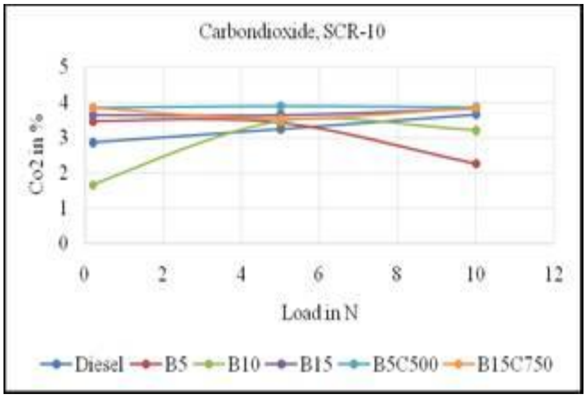

Figure13. Carbon Dioxide vs Load at SCR-1

IV. CONCLUSIONS

1) The properties of Biodiesel & Biodiesel – Nanoparticle blends resembles closely to that of commercial diesel.
2) These are relatively economic than diesel and emits less pollutants. It can be used for Vehicular use, Railway usage, as heating oil when blended with other fuel oil in proportion. Flash & fire points are significantly lower than diesel.
3) Densities of Bio- Diesel & Nano Particle blends are less than the density of Diesel (850.768 kg/m3)
4) The CV values of blends are approximately equal to the CV of Diesel (44631.96 MJ/kg) and especially B5C500 (45320.0850 MJ/kg) has More CV than Diesel. Hence these can be used as Bio – Diesels.
5) Mechanical Efficiency for Bio – Diesel & Nano Particles especially B15C750 is more than the Pure Diesel. Thus, it can be used as biofuel.
6) Emissions have also been reduced a little bit, Carbon Residue of Bio – Diesel with Nano Particles is very less and hence resulting in less particulate matter.
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.

V. ACKNOWLEDGEMENTS

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