Influence of Nanoparticles Addition on Performance of CSOME in DI CI Engine

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Abstract. In this work it is aimed to test the performance of cotton seed oil biodiesel with cerium oxide (CeO_2) nanoparticles as additive. This work goes through the various stages like production of biodiesel, addition of nanoparticles with the biodiesel-diesel blends in different proportion using ultrasonicator, testing the effect of nano additives on physiochemical properties of the fuel blend, testing the stability of fuel blend with nano particles, testing the performance and exhaust emission in diesel engine. The blends B10 (90% diesel and 10% biodiesel in volume), B20 (80% diesel and 20% biodiesel in volume), B20+50ppm (80% diesel and 20% biodiesel and 0.05 gm/l cerium oxide) in volume, B20+100ppm (80% diesel and 20% biodiesel and 0.1 gm/l cerium oxide) in volume, B25 (75% diesel and 25% biodiesel) in volume were prepared. From the performance test results, the cotton seed oil fuel blended with cerium oxide shows increment in brake power 4.5kW 4.68kW and brake torque of 18.43 Nm and 18.52 Nm with 50 ppm and 100 ppm respectively. Addition of CeO_2 improved exhaust emission compared to pure diesel (B0). The brake specific fuel consumption of cotton seed fuel blended with cerium was decreased compared to the diesel. Generally, it may be concluded from the experimental investigation that the cotton seed oil biodiesel fuel blended with cerium oxide nanoparticle can become a good alternative to petro-diesel.

Keywords: Biodiesel · CeO_2 nanoparticles · Performance and emission · Stability of the blend · Ultrasonicator

1 Introduction

The growing industrialization and motorization of the world has led to a step up for the demand of petroleum-based fuel. The petroleum-based fuels are obtained from restricted reserves. These finite reserves are highly targeted in certain areas of the world. Therefore, those countries not having these resources face energy/foreign exchange crisis, principally because of the import of crude petroleum. Hence, it's necessary to appear for alternative fuels which might be produced from resources accessible domestically among the country such as alcohol, biodiesel, vegetable oils etc. [1]. To solve this issue, many researchers established with results that biodiesel is an alternate fuel.

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It is evident that two things are necessary, one is process of vegetable oil to biodiesel and the alternative is testing obtained biodiesel in diesel engine for its compatibility as fuel to diesel engine particularly the blend percentage which will offer results almost like diesel. Biodiesel is outlined as mono-alkyl esters of long chain fatty acids derived from renewable biolipids via transesterification method, that conform to ASTM D6751 specifications to be used in diesel engines [1]. The method of elimination all glycerol and fatty acid from the vegetable oil within the presents of catalyst are called as transesterification. It's basically a written record reaction. Triglycerides are first reduced to di glycerides. The di glycerides are afterwards reduced to mono glycerides. The mono glycerides are finally reduced to fatty acid esters [2].

The properties of biodiesel typically have higher density, viscosity, cloud point, cetane number, lower volatility and heating value The properties of biodiesel typically have higher density viscosity cloud point cetane number lower volatility and heating value compared with diesel fuel that affecting on engine performance and emissions. However, using optimised blend of nano particles and diesel will help to reduce these high properties or its blends could also be used in the present diesel engines with very little or no modification to the engine [4, 8]. With the following goals and method this work has been completed through fuel additives (nanofuel). Nanofuel could be a renewable and ecofriendly alternative diesel fuel for CI engine. What are more additives being an important a part of these days fuels, along with the carefully developed fuels composition. They contribute to efficiency responsibility associated long lifetime of an engine like using optimised blend of nano particles and diesel rather than conventional diesel fuel considerably reduces emission of particulate matters (PM), carbon monoxide (CO), sulphur oxides (SOx), and unburned hydrocarbons (HC). With the utilization of fuel additives within the blend of nanoparticles and diesel improves performance, combustion and additionally improves fuel properties that enhance the combustion characteristics. The impact of mixture of cerium oxide (CeO_2) and carbon nanotube (CNT) in single cylinder four-stroke water-cooled inconstant compression ratio engine using castor biodiesel blend with ethanol. When blended at 25ppm, 50ppm and 100 ppm of 32 nm sized CeO_2 and 100 nm sized CNT, brake thermal efficiency and cylinder pressure is increased. Moreover, such a blend of nano particles resulted in forward-looking peak pressure incidence with cleanser combustion means reducing emission [8]. This work study was designed to analyze the result of CSME blended with diesel beside cerium oxide (CeO_2) nanoparticle on the performance and exhaust gas characteristics of diesel engine. For investigation varied blends of cotton seed biodiesel with diesel were taken. The cerium oxide (CeO_2) nano particle was added with various proportions [5]. The researchers are targeted on single biodiesel with Nano fuels blends like soybean oil, rapeseed oil, pongamia pinnata oil, Cotton seed oil, Neem oil, Castor oil, Mahua oil, Mahua oil, jatropha oil, lineed oil, rice bran oil etc. and its blended with diesel [5, 6]. The stability of nano fluid is increase by ultrasonic bath stabilization or by adding chemical agent within the fluid [7].

Nanoparticles acts as a fuel accepted catalyst that improves specific properties of fuel once value-added to the base fuel depending upon the dosage level of it (i.e., flash point, fire point, kinematic viscosity, heating value and cetane number). This can be because of its better thermo physical properties. Particles that have size in between one nm to one hundred nm are thought about as nanoparticles. The size of nanoparticles varies from 1 to 100 nm [9–12]. The experimental on emission characteristics, performance with Hinge oil methyl ester (HOME) biodiesel fuel blended with multi walled carbon tube (MWCNT) at 25 ppm and 50 ppm concentration in single cylinder four stroke direct injection diesel engine [13–16]. In addition, the investigation of emission characteristics and performances of pure diesel and diesel-biodiesel blend and ethanol blends with 25 ppm cerium oxide (CeO_2) [17–19].

2 Materials and Methods

The cotton seed was obtained from awash. Methanol, potassium hydroxide, and distilled water were purchased from chemical marketing and suppliers companies (Ranchem chemicals Plc, Addis Ababa) for laboratory scale amount. Cerium oxide (CeO_2) nanoparticle were purchased from Nano Research Lab, India; diesel fuel was purchased from Oil Libya Adama. All chemicals used for the research were analytical grade. Characterisation of fuel blends were tested at Ethiopian petroleum supply and enterprise while the performance and exhaust emission test was conducted at Dilla University Mechanical Engineering laboratory on CT 110 Test Stand Diesel Engine (single cylinder, 4-stroke engine).

2.1 Extraction of Cotton Seed Oil

The raw Cotton seed were obtained from cotton ginning factory Awash and separated the seed from the lint before the oil extracted from the seed. The lint goes to textile industry and the seed for the oil extraction to Hundaf Engineer Food oil production Plc. There are some core procedures to be followed for extracting crude oil from cotton seed. The steps are like collection of all cotton seeds, de hulling and separation of the hulls (husk), cleaning the seed and drying, mechanical press, heat treatment and cooking and filtering. Figure 1 shows the pressing of cotton seed using screw press.

After the crude oil was extracted using screw press, the transestification was done at Adama Science and Technology University, Chemistry Department Laboratory.

Fig. 1. Extraction of oil from cotton seed by screw pressing.

2.2 Determination of Acid Value

2.2.1 Titration

In order to determine the percent of FFA in the oil, a process called titration is used. The vegetable oil is first mixed with methanol. Next, a mixture of sodium hydroxide (NaOH) and water is added till all of the FFA has been reacted. This can be confirmed by checking the pH of the mixture. If the oil samples have high FFA content (more than 1%) then the reaction consumes more alkali catalyst to neutralize the FFA. The FFA content in the oil was found as 0.59. The FFAs < 1, therefore transestirification process was used to prepare biodiesel. Figure 2 shows the titration of crude oil.

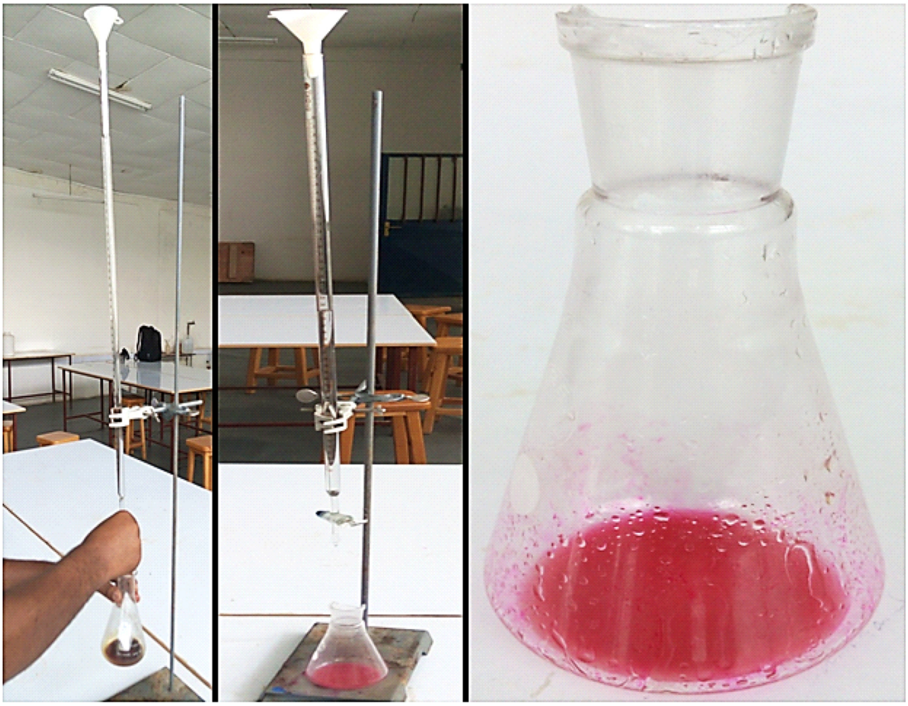

Fig. 2. Titration to find FFA in the oil

2.2.2 Laboratory Preparation of Biodiesel (Transestirification Process)

The biodiesel production using transesterification process involves various stages.

Fig. 3. Transesterification

Fig. 4. Glycerol Separation from methyl ester

Fig. 5. Washing biodiesel (soap is at bottom)

Fig. 6. Final washing of biodiesel

Fig. 7. Drying of biodiesel

Fig. 8. Prepared biodiesel

The figures Fig. 3, 4, 5, 6, 7 and Fig. 8 show the stages of biodiesel production like transesterification using hotplate with magnetic stirrer, separation of glycerine, washing of biodiesel with water (First washing and Final washing), biodiesel drying and finally the prepared biodiesel.

2.2.3 Mixing Nanoparticles with Fuel Blend

The cerium oxide nanoparticles were mixed with B20 at a proportion of 50 ppm and 100ppm using magnetic stirrer and ultrasonic cleaner for homogeneous dispersion of nanoparticles in the blend. Stable mixture was obtained adding CTAB surfactant.

Blending of nanoparticles was done using ultrasonic cleaner with a frequency of 40 kHz for about 30 mnts. Figure 9 shows the ultrasonic cleaner and the prepared blends. Figure 10 shows all fuel blends prepared.

Fig. 9. Ultrasonicator and fuel blends

Fig. 10. Prepared biodiesel blends

3 Experimental Setup

The performance and exhaust emission tests were conducted on CT 110 Test Stand for Small Combustion Engine. The specifications of the test stand are given in the Table 1. Figure 11 Shows the picture of the experimental setup.

Table 1. Specification of the CT 110 Test Stand with engine

Engine model	1B30-2
Number of cylinders	1
Length × Width × Height	370 mm × 330 mm × 450 mm
Company	Hatz
Weight	35 kg
Fuel	CT 100.22 Diesel

(*continued*)

Table 1. (*continued*)

Bore	80 mm
Stroke	69 mm
Crank length	34.5 mm
Rod length	114.5 mm
Output power at 3500 min-1	5.5 kW
Oil capacity	1.1 L
Stop solenoid	12 V
Compression ratio	22: 1
Engine type	Air-cooled single cylinder 4-stroke Diesel Engine

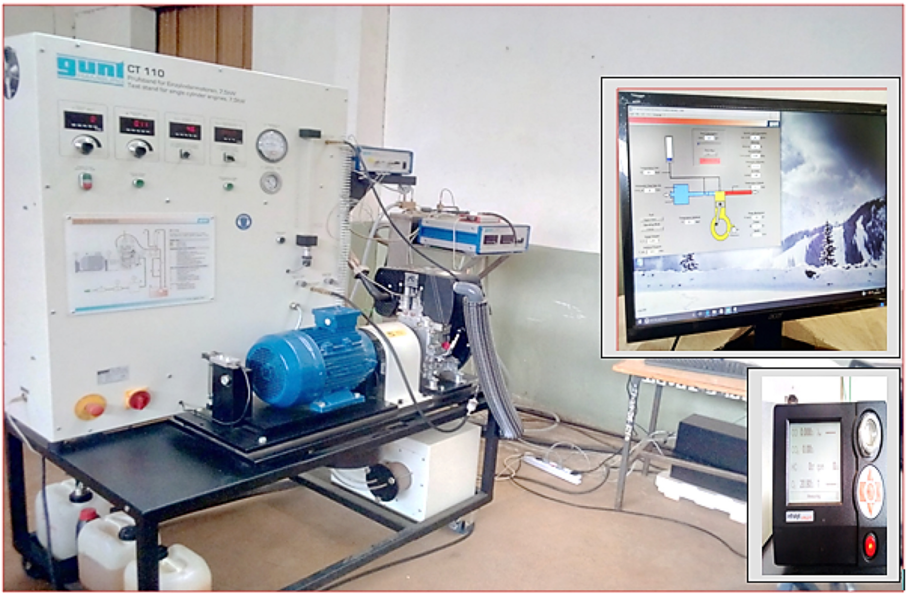

Fig. 11. Experimental setup

4 Result and Discussion

4.1 Characterization Results

The characterization results of the biodiesel produced from cotton seed oil and blend fuels that were certified from Ethiopian petroleum supply enterprise are shown in Table 2.

Table 2. The properties of biodiesel and blends.

SNo	Properties	Test method ASTM	EPSE Diesel limits	Results					
				B100	B10	B20	B25	B20+50ppm CeO_2	B20+100ppm CeO_2
1	Density@15 °C (g/ml)	D4O52	Report	0.8563	0.8425	0.8467	0.8488	0.8477	0.8464
2	Density@20 °C (g/ml)	D4052	Report	0.8465	0.8389	0.8432	0.8454	0.8442	0.8458
3	Flash Point (PMCC, °C)	D93	Min.60	182	85	86	89	87	86
4	Cloud point (°C)	D2500	Max.+5	+3	+1	−1	+2	+1	+1
5	Total acidity (mgKOH/g)	D974	–	0.0985	0.0852	0.1009	0.0918	0.0930	0.1005
6	Viscosity@40 °C (cSt)	D445	1.9–6	3.67	3.29	3.32	3.33	3.32	3.31

4.2 Engine Brake Power (kW)

From the Fig. 12, it is observed that, the maximum brake power was developed at 2808 rpm for the fuels tested. The highest values of brake power for B0, B10, B20, B25, and B20 + 50 ppm CeO_2, B20 + 100ppm CeO_2 are 5.18 kW, 4.67 kW, 4.60 kW, 4.31 kW, 4.53 kW and 5.21 kW respectively.

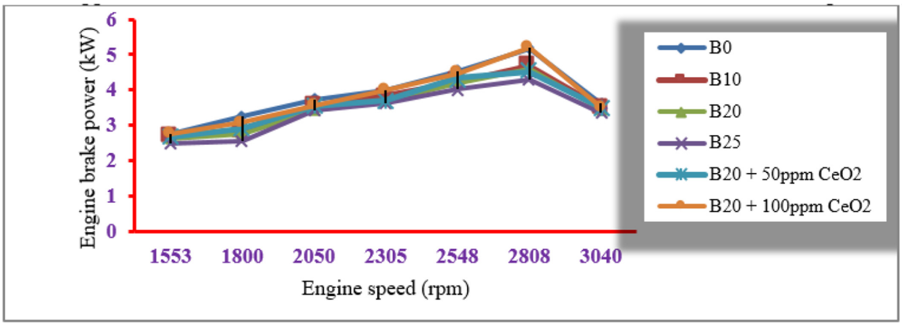

Fig. 12. Variation of Brake power (kW) with Engine speed (rpm)

4.3 Engine Brake Torque (Nm)

From Fig. 13, given below, it is observed that all fuel samples producing maximum torque at a speed of 2548 rpm. The maximum brake torque for the fuel samples B0, B10, B20, B25, B20 + 50 ppm CeO_2 and B20 + 100 ppm CeO_2 are 18.48 Nm, 18.35 Nm, 18.12 Nm, 17.83 Nm, 18.43 Nm, and 18.52 Nm respectively. B20 + 100 ppm CeO_2 had higher brake torque than other fuel blends. It is clearly observed that the addition of CeO_2 caused higher brake torque.

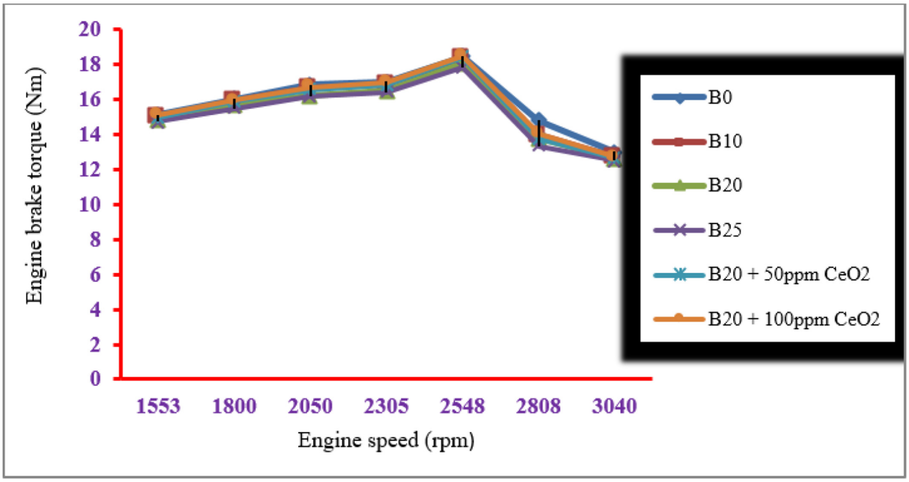

Fig. 13. Variation of Brake torque (Nm) with Engine speed (rpm)

4.4 Brake Specific Fuel Consumption Bsfc (kg/kWh)

Figure 14 below shows that there is a reduction of brake specific fuel consumption with addition of nanoparticles. Engine speed for neat diesel, biodiesel blend fuel and biodiesel blend fuel plus cerium oxide nano particles. The bsfc was observed to be reducing from 1553 rpm to 2548 rpm later starts increasing.

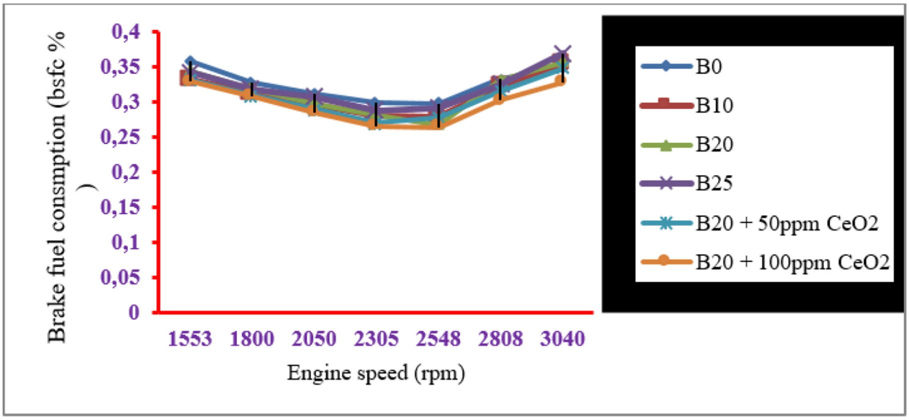

Fig. 14. The variation of brake specific fuel Consumption (kg/kWh) with engine speed (rpm)

4.5 Carbon Monoxide Emission (CO %)

Figure 15 shows the variation of CO emission with speed for different fuel blends. Reduction of CO with the addition of CeO_2 is clearly indicated. At higher speeds there is a reduction tendency of CO with CeO_2 addition.

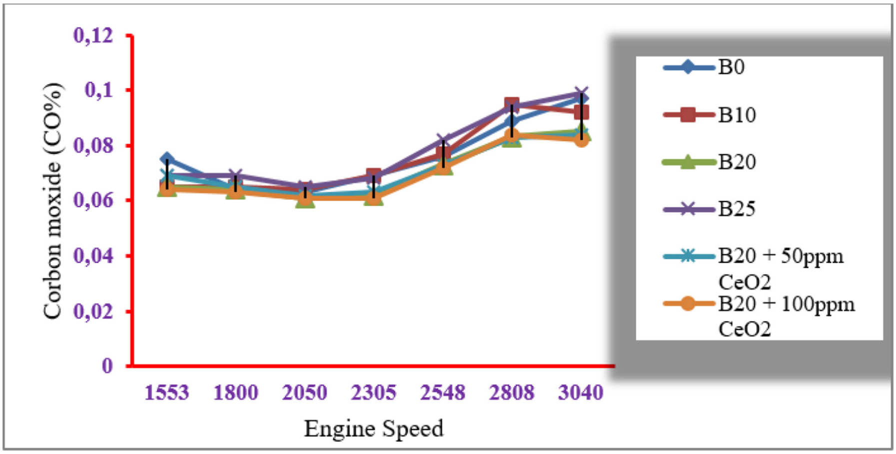

Fig. 15. Variation of carbon monoxide (%) with respect to engine speed (rpm)

4.6 Carbon Dioxide Emission (CO_2 %)

From Fig. 16, it can be seen that CO_2 emission is less for all biodiesel blends compared to diesel fuel. Especially in B20 + 100 ppm CeO_2 the reduction of CO_2 is more than others blends. The reduction of CO_2 at low engine speed 1553 rpm is 2.53%, 2.38%, 2.47% 2.52%, 2.32% and 2.28% respectively compared to diesel.

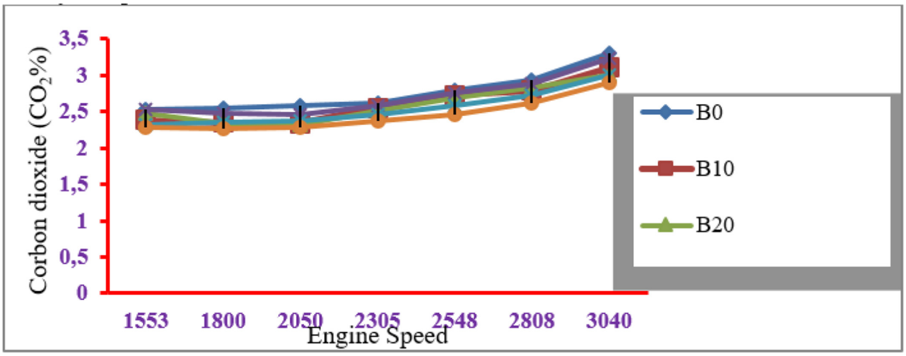

Fig. 16. Variation of carbon dioxide (%) respect to engine speed (rpm)

4.7 Hydrocarbon Emission (HC ppm)

B20 + 50ppm CeO_2 and B20 + 100 ppm CeO_2 fuel blends had less HC emission than others Fig. 17.

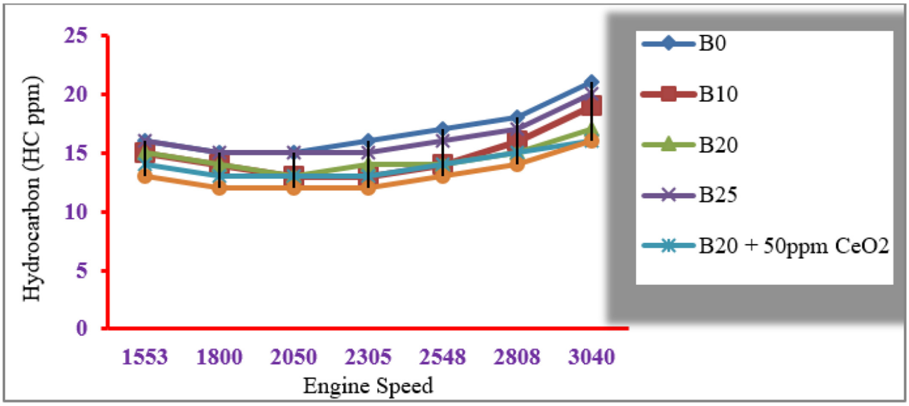

Fig. 17. Variations of Hydrocarbon (HC) respect to Engine speed (rpm)

4.8 Emission Test for (O2%)

The oxygen (O_2) in case of fuel blended with cerium oxide nano particle is somewhat higher than other fuels. For a blend of B20 + 100 ppm CeO_2 the O_2 emission is 17.56%, 17.55%, 17.49%, 17.33%, 17.29%. 17.18%, 16.99% higher for engine speeds 1553 rpm, 1800 rpm, 2050 rpm, 2305 rpm, 2548 rpm, 2808 rpm, and 3040 rpm respectively, than diesel fuel (Fig. 18).

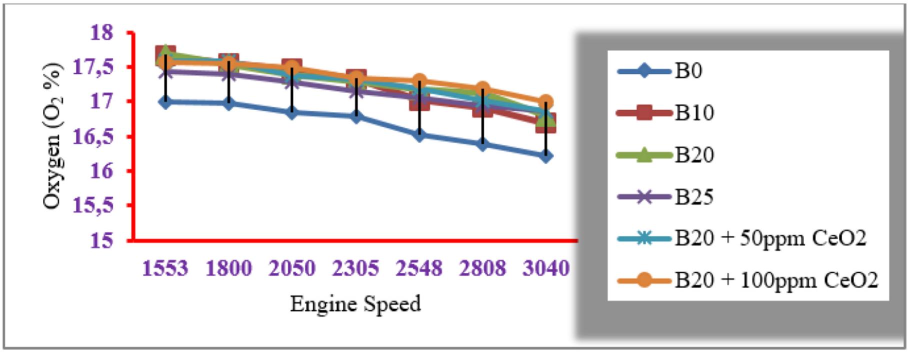

Fig. 18. Variations of oxygen (O_2) respect to Engine speed (rpm)

5 Conclusion

Based on engine performance and exhaust emission tests, it can be concluded that diesel biodiesel fuel blends with CeO_2 can be used satisfactorily in diesel engine without any modifications of the engine. Transesterification reduced the viscosity of the oil considerably and addition of CeO_2 also caused slight reduction in viscosity (3.67cSt, 3.29cSt, 3.32cSt, 3.33cSt, 3.32cSt, and 3.31cSt for biodiesel, B10, B20, B25, B20 + 50ppm CeO_2, and B20 + 100ppm CeO_2 respectively). These results were nearly close to diesel and confirm with the biodiesel standards (ASTM D6751). From the engine performance test and emission test, it is clearly observed that the addition of CeO_2 caused better performance and less harmful emissions compared to conventional diesel.

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