Experimental investigation of effect of cerium oxide nanoparticles as a fuel additive in cottonseed biodiesel blends

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***Abstract*- As the reserves of fossil fuels are depleted progressively & Fuel energy is need of growing economy so, in order to fill the gap between demand and supply we must need to find out the alternative source of fuel supply. Biodiesel is one of the promising sources which reduce the emissions of CO, HC, and Sox but due to more oxygen content in biodiesel nearly 16% greater than neat diesel the harmful emissions of NO_x are increases, to minimize this NO_x emissions metal oxide nanoparticles has recently added as a fuel additive. In these experimentation Cerium Oxide Nanoparticles in 50 PPM concentration is used in cottonseed biodiesel blends $10CSBCeO_250$ & $20CSBCeO_250$. The experiments were carried out on single cylinder D.I. diesel engine running at 1500 RPM by varying load from 0 to 6 kg and compression ratio 14 to 18. Results show the significant improvement in performance parameters and reduction in NOx emissions.**

***Keywords*: Nanoparticle, alternative fuel, biodiesel, performance, emission, CeO_2, NO_x.**

I. Introduction & Background

Biodiesel refers to any diesel fuel alternative derived from renewable biological resource. More specially, biodiesel is defined as oxygenated, sulfur-free, biodegradable, non-toxic and eco-friendly alternative diesel oil. India imports 70% of petroleum products to satisfy the demand. Currently Indian annual requirement for petroleum products is about 120 million metric tons of which the diesel consumption is approximately 40 million tones. Biodiesel fuel has the potential to reduce the level of pollutants and has better properties than that of petroleum diesel. The source of Biodiesel in the form of vegetable oils, non-edible oils, animal fats and some other biomass. Addition of nanoparticles in diesel and diesel-biodiesel blends not only enhances the calorific values but also promotes complete combustion due to higher evaporation rates, reduced ignition delay, higher flame temperatures and prolonged flame sustenance. All these factors support the full release of thermal energy thereby leading to higher brake thermal efficiency and lower BSFC. The principle of this additive action consists of a catalytic effect on the combustion of hydrocarbons. Use of transition (or) noble metals in the form of fuel additives lowers the soot ignition temperature. The metal additive in the diesel fuel changes the cetane number (by about 1.2 percent) and affects combustion and emissions. Fuels with a high cetane number have smaller premixed fuel portions and lower NO_x emissions for the same BMEP compared to lower cetane number. Some metal-based additives are effectively reduces diesel emissions.

Many of the researchers' had work on chemical enhancement of fuel blends of various biodiesels by mixing additives like nanoparticle`s of metal oxides such as cerium oxide, titanium oxide, aluminum oxide etc. the test were conducted on 4-Stoke single cylinder D.I. diesel engine with variable compression ratio & they found effective changes on performance & emissions parameters of the engine. A.C. Sanjeevan [1] found that the addition of cerium oxide nanoparticle`s improves the properties of the fuel blends and brake power also improves. Renaware A. A [2] found that there is successful reduction in $No_x$ emission by addition of Cerium oxide nanoparticle`s in various proportion in biodiesel blends.

II. RESEARCH GAP

As per central pollution control board under the ministry of environment, forest & climate change new engine emission norms are regulated in India from 1st April 2017 onwards [3]. So, to find the solution over this problem this experimentation is carried out. Most of researchers' are already tested various biodiesel blends by addition of various metal oxide nanoparticle`s on variable compression diesel engine but very few researchers uses the cerium oxide nanoparticle`s for study and no one tested the blends of cottonseed biodiesel blends with cerium oxide nanoparticle`s on VCR diesel engine.

III. EXPERIMENTAL STUDY

The experimentation of this research work is carried out mainly in two phases in first phase the properties of fuel blend like density, viscosity, flash point, fire point, calorific value were tested as per ASTM standards procedure. In second phase the performance parameters like brake power, brake specific fuel consumption, fuel consumption, brake thermal efficiency, and exhaust gas temperature were measured on VCR diesel engine & Ozone exhaust gas analyzer. The following procedure is followed during experimentation.

A. Preparation of fuel blends

Base fuel used in this investigation is diesel & cottonseed biodiesel which is produce from cottonseed oil by trans-esterification process. Basically two diesel-biodiesel blends were prepared and the cerium oxide nanoparticle`s then added in those blends. All those four blends with pure diesel then tested in the experimentation the fuel chart shows the detail proportion of diesel, biodiesel & cerium oxide nanoparticle`s in blend. The addition of cerium oxide nanoparticle`s with blends of cottonseed biodiesel is carried out by ultra-sonication process. The oleic acid is added as a surfactant in that blends to improve the stability of nanoparticle`s in biodiesel fuel blends.

TABLE I. Fuel Blends Chart

Fuel Type	Description
100D	100% diesel by volume
10CSB	10% cottonseed biodiesel & 90% diesel by volume
20CSB	20% cottonseed biodiesel & 80% diesel by volume
10CSBCeO2 50	10% cottonseed biodiesel & 90% diesel by volume with 50 PPM concentration of CeO2
20CSBCeO2 50	20% cottonseed biodiesel & 80% diesel by volume with 50 PPM concentration of CeO2
100D	100% diesel by volume
10CSB	10% cottonseed biodiesel & 90% diesel by volume

Figure 1. Fuel Blends of cottonseed biodiesel.

B. Determination of fuel properties

The properties of fuel blend like density, viscosity, flash point, fire point, calorific value were tested as Per ASTM standards procedure & tabulated in Table II. The properties of the fuel blends plays important role in Combustion of fuel blends.

TABLE II. Fuel Properties

Sr. No.	**Properties**	**100D**	**100CSB**	**10CSB**	**10CSB $CeO_2$50**	**20CSB**	**20CSB $CeO_2$50**
1	**GCV, Kcal/kg**	10571	8725	10401	10936	10389	10708
2	**Viscosity @40 ^oC, mm^2/sec**	3.92	6.15	4.29	5.29	4.94	5.31
3	**Flash Point, 0_C**	53	108	60	64	73	76
4	**Density, gm/ml**	0.817	0.8922	0.827	0.8349	0.836	0.839

C. Engine setup & specification

The engine setup consists of single cylinder, four stroke, VCR (Variable Compression Ratio) Diesel engine connected to eddy current type dynamometer for loading. Without stopping the engine the compression ratio can be changed and without altering the combustion chamber geometry by specially designed tilting cylinder block arrangement. Engine setup is as shown in fig 2 & Specifications are tabulated in table III

TABLE III. Engine Specification.

VCR Diesel Engine Specification	
No. of cylinders	1
Brake power	3.5 kw
RPM	1500rpm (constant)
Bore	87.5mm
Stroke	110mm
Capacity	661 cc
Loading type	Eddy current dynamometer
Cooling	water cooled
Compression Ratio	12-18
Temperature sensor	Type RTD, PT100 and Thermocouple, Type K.
Temperature Transmitter	Input RTD PT100 Type two wire,
Load indicator	Digital, Range 050 Kg, Supply 230VAC
Fuel flow transmitter	DP transmitter, Range 0500 mm WC
Air flow	Pressure transmitter, Range , Transmitter 250 mm WC

Figure 2. VCR Diesel Engine Setup

IV. RESULTS AND DISCUSSION

A. Viscosity & flash point

The variation of kinematic viscosity & flash point for different blends of biodiesel with and without cerium oxide nanoparticles were shown in figure It was seen that kinematic viscosity & flash point of biodiesel blend was further increased when dispersed 50 PPM concentration of nanoparticles. Maximum kinematic viscosity & flash point was observed for 20CSBCe$O_2$50 blend. Optimum value of viscosity reduces the pumping power & poor combustion of fuel while, higher value of flash point is suitable for safely handling of fuel.

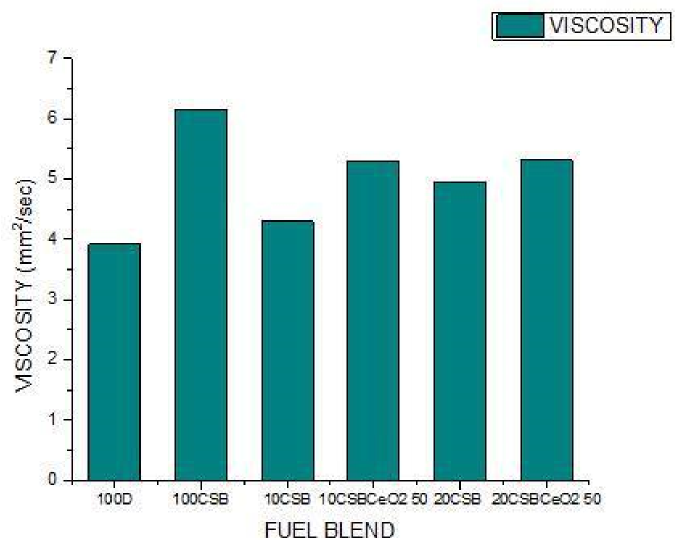

Figure4. Viscosity of fuel blends

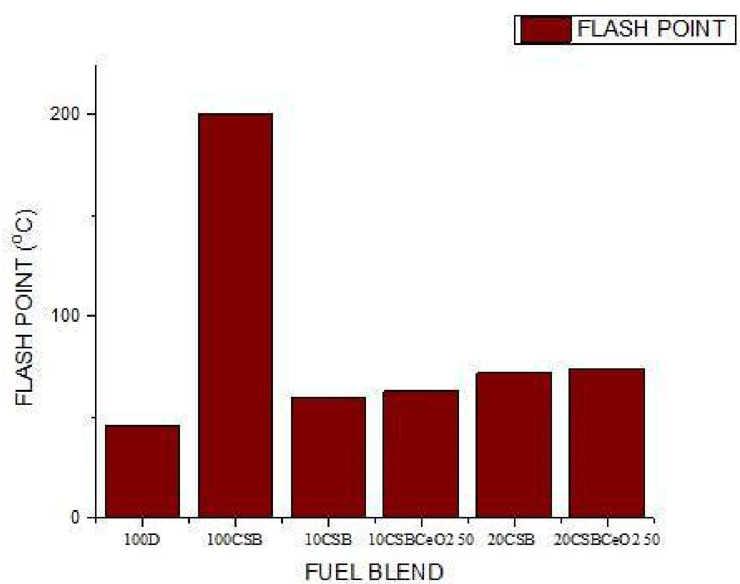

Figure5. Flash Point of fuel blends

B. Performance parameters

1. Brake power

At compression ratio 14 & higher load of 6 kg 10CSB blend produce more power than diesel due to excess of oxygen available for proper combustion but for 20CSB fuel blend due to lower calorific value, higher density & higher viscosity brake power decreased. The cerium oxide nanoparticle`s added fuel blend 10CSBCeO$_2$ 50 produce maximum brake power among all blends. Nanoparticle`s of cerium oxide act as an oxygen buffer & promotes the proper combustion which increases the brake power.

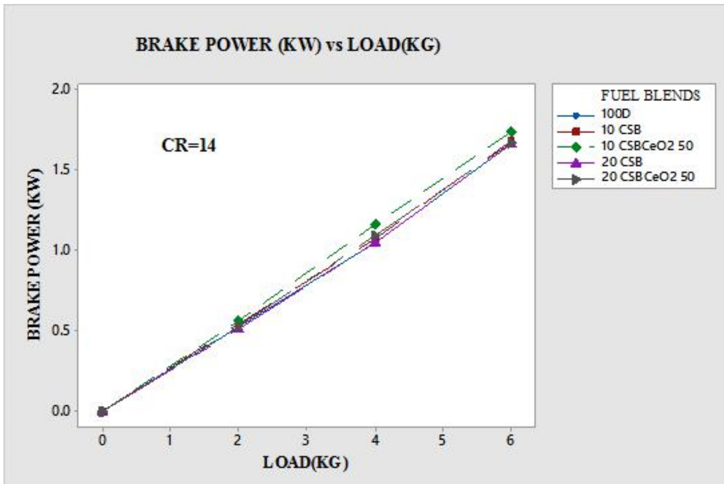

Figure6. Variation of BP with respect to load at compression ratio 14

2. Brake thermal efficiency

The graph shows that the brake thermal efficiency increases as the load increases & decreases as the contain of cottonseed biodiesel increases in diesel-biodiesel blends, because the biodiesel possess low volatility, low calorific value, high density & viscosity which leads the higher fuel consumption. Cerium oxide nanoparticle's store & release the oxygen which increases the brake thermal efficiency. Nanoparticle`s helps to improve the rate of evaporation, reduce the physical ignition delay, improves calorific value & flame temperature. The blend 10CSBCeO$_2$50 shows maximum brake thermal efficiency at compression ratio 14.

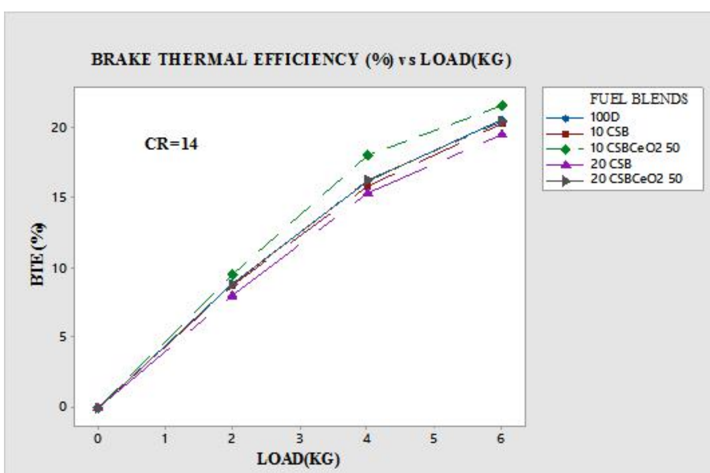

Figure7. Variation of BTE with respect to load at compression ratio 14

3. *Fuel consumption*

Experimentally it was observed that the fuel consumption increases as the load on engine increases & found to be higher for 10CSB & 20CSB due to lower calorific value, higher viscosity, and higher density. Cerium oxide nanoparticle`s reduces the carbon deposit formation inside the wall of engine cylinder which reduces the frictional power. Due to good atomization, proper mixing of fuel & higher calorific value reduces the fuel consumption & found to be minimum for 10CSBCeO_2 50 at compression ratio 14. At higher compression ratio fuel dilution take place that therefore minimum fuel consumption observed at compression ratio 14.

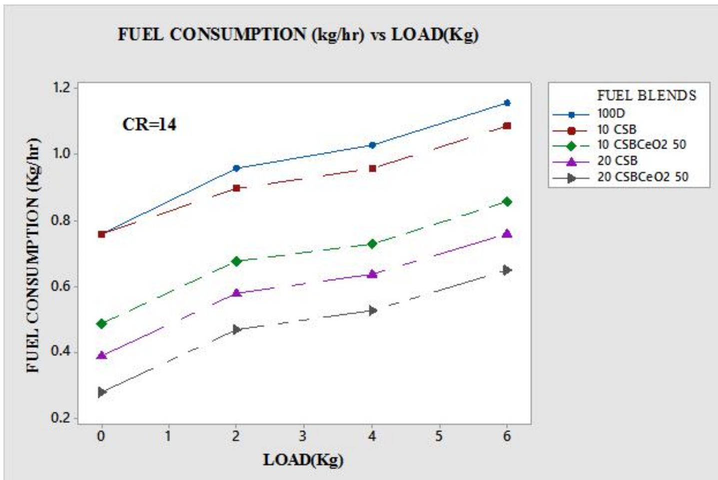

Figure8. Variation of Fuel Consumption with Respect to load at compression ratio 14

4. *Brake specific fuel consumption*

Brake specific fuel consumption decreases continuously for all blends of biodiesel as well as for neat diesel as the load increases. However the percentage of biodiesel increases in the blends the BSFC increases, due to higher viscosity & density of fuel blends. When cerium oxide nanoparticle`s added in the blends & tested it found that the phenomenon of physical ignition delay, enhanced surface are to volume ratio & proper combustion lowers the BSFC. The lowest BSFC found for 10CSBCeO_2 50 at compression ratio 14.

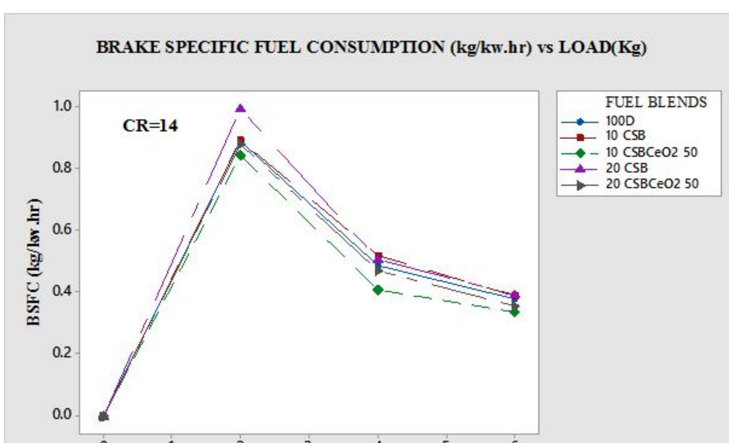

Figure9. Variation of Brake Specific Fuel Consumption with respect to load at compression ratio 14

5. *Exhaust gas temperature*

It observed that the exhaust gas temperature of all blends with or without nanoparticle`s are found to be higher than that of the pure diesel. It was happened due to higher oxygen contain in biodiesel. The exhaust gas temperature increase with load & found higher for 20CSB fuel at full load but it is lower for 20CSBCe$O_2$ 50 due to addition of nanoparticle`s in blends which reduces the carbon deposit & increase the rate of heat transfer.

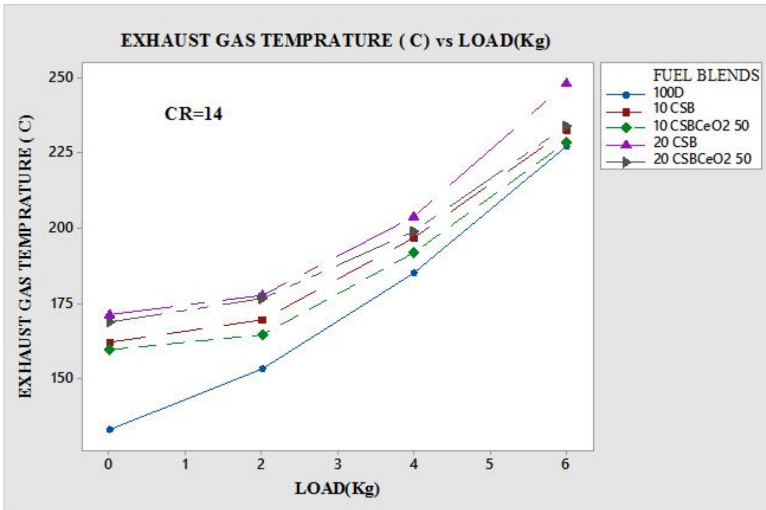

Figure10. Variation of Exhaust Gas Temperature with respect to load at compression ratio 14

C. Emission parameters

1. NO_X emissions

The biodiesel blends shows more NO_X emission as compared with neat diesel as the biodiesel contain more oxygen than diesel. At higher temperature the oxygen in air mixed with nitrogen & formation of NO_X take place which increases by lower ignition delay of biodiesel. Addition of CeO_2 nanoparticle`s significantly reduces the NO_X emission and found least for 10CSBCeO_2 50 at compression ratio 14. It happens because of complete combustion take place in the combustion chamber which prevents formation of carbon deposit on cylinder wall of the engine & heat transfer rate increases which reduces NO_X.

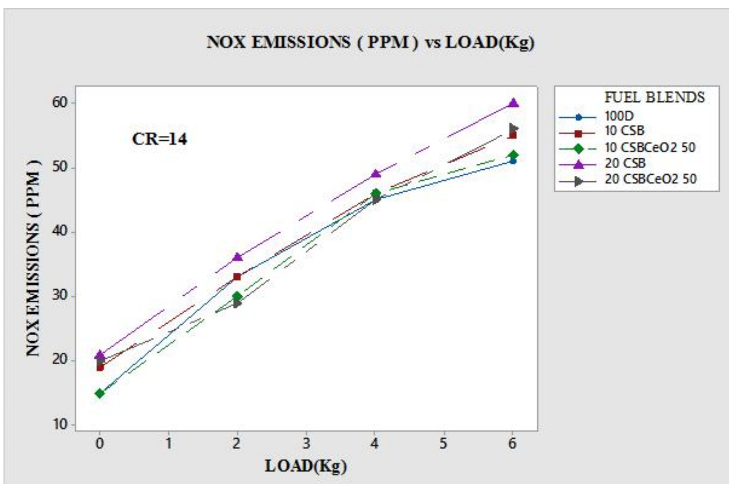

Figure11. Variation of NO_X emission with respect to load at compression ratio 14

2. CO emissions

The CO emissions for pure diesel is found to be highest among all the fuel blends due to unborn carbon & lack of oxygen available for conversion of CO to CO_2 which emits more carbon monoxide. 10CSB & 20CSB shows better result than pure diesel but addition of nanoparticle`s of CeO_2 acts as a oxygen buffer & reduce CO emissions. The least CO emissions found for 20CSBCeO₂ 50. Among the compression ratio 14, 16, 18 the lowest CO found at CR 14 due to decrease in Air- fuel ratio.

$$2CeO_2 + CO \longrightarrow CeO_3 + CO_2 \quad (1)$$

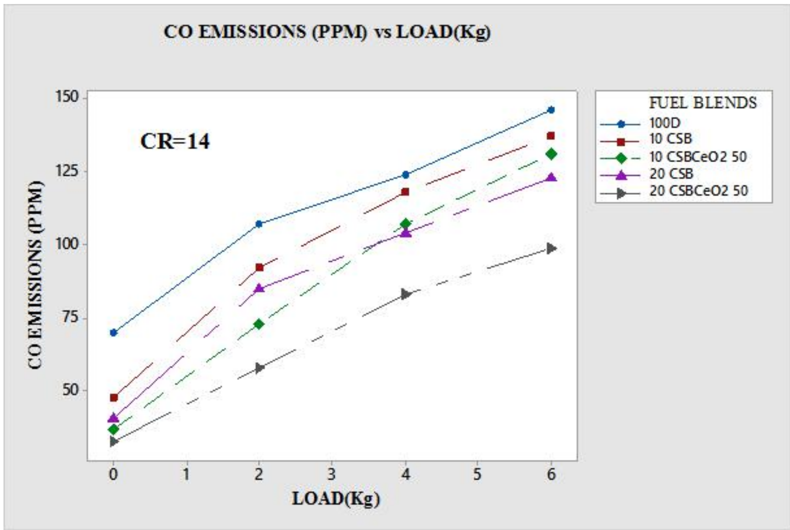

Figure12. Variation of CO emission with respect to load at compression ratio 14

3. HC emissions

At no load & higher compression ratio HC emissions are found to be higher for 10CSB & 20CSB because of higher surface tension which increase the viscosity & lower the compressibility. Cerium oxide nanoparticle`s provide more surface are & proper combustion which minimize the combustion.

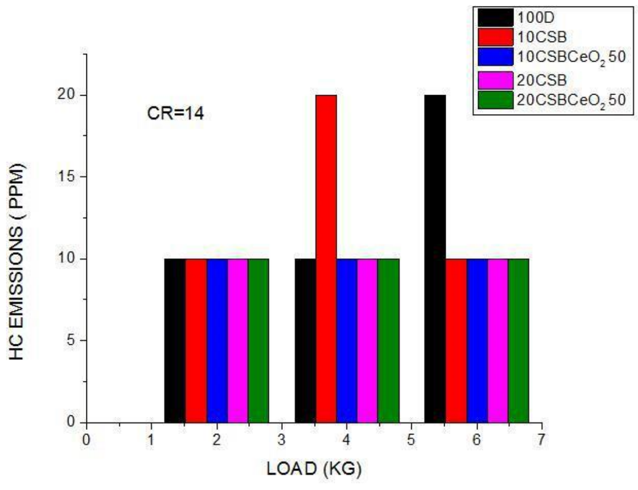

Figure13. Variation of HC emission with respect to load at compression ratio 14

V. CONCLUSIONS

The objective of the research is to find out the effect of cerium oxide nanoparticle`s as a fuel additive for cottonseed biodiesel blends so, after experimentation on 4 - stroke singe cylinder D.I. diesel engine with variable compression ratio following conclusions were obtained.

A. Fuel properties

- Both the viscosity & Flash Point of the blends increases with addition of cerium oxide nanoparticles.
- The gross calorific value of the blend 10CSBCeO250 is found to be 3.33% more than neat diesel.

B. Optimum compression ratio

- Brake power & Brake Thermal Efficiency was found to be higher at CR 14.
- Minimum BSFC & Fuel Consumption was observed for CR 14.
- Lowest NOX, CO, HC emissions were found at CR 14.
- So CR 14 was found as the optimum Compression ratio.

C. Performance & emission characteristics

- The blend $10CSBCeO_250$ released 1.69 KW brake power at CR 14 which is maximum. & it was 4.53% & 3.45% higher than the pure diesel & 10CSB respectively.
- Brake thermal efficiency of $10CSBCeO_250$ was evaluated 4.5% & 5.99% more than pure diesel & 10CSB.
- Fuel Consumption for $10CSBCeO_250$ at CR 14 was found to be 1.78% & 1.67 % less as compare with diesel & 10CSB.
- Similarly BSFC for $10CSBCeO_250$ was found to 0.335 Kg/Kw.hr which is 0.44% & 0.53% less than BSFC of diesel & 10CSB which is 0.379 Kg/Kw.hr & 0.388 Kg/Kw.hr respectively.
- Experimentally it was found that the $10CSBCeO_250$ shows the highest exhaust gas temperature among the all fuel blend.
- At compression ratio 14 $10CSBCeO_250$ emits minimum NOX emission compare with diesel & biodiesel blends. The NOX emission was 5.45% less than 10CSB.
- CO emissions decreases by 32.19% & 10.27% respectively for $10CSBCeO_250$ & $20CSBCeO_250$ as compare with neat diesel.
- HC emissions were nearly permissible for all blends & Found within limit.
- The fuel blend $10CSBCeO_250$ was found to be optimum for all performance & emissions parameters were measured.

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