Cerium Oxide Nano Particles as Addiditve with Diesel Fuel on DI Diesel Engine

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***Abstract*—This paper reports on the use of cerium oxide nanoparticles (CEONP) as additive to the diesel fuel and the effects of their operational characteristics like performance and emission of the DI diesel engine. In this study, the tested fuels were prepared by blended cerium oxide nanoparticles into the diesel fuel at the mass fraction of 25ppm and 50ppm with the help of a mechanical homogenizer and an ultrasonicator. Based on the experimental results, HC, CO emissions and smoke noticeably decrease, while NOx emission dramatically increases with increasing the dosing level of cerium oxide nanoparticles. At the full load, the magnitude of HC and CO for the neat diesel was 104 ppm and 51 (% by volume), whereas it was 68 ppm and 20 (% by volume) for the CMNT50 fuel, respectively. The results also showed a significant enhancement in brake thermal efficiency and heat release rate due to the influence of the cerium oxide nanoparticles addition in diesel.**

Keywords*— Cerium oxide nanoparticles (CEONP), Diesel Engine, Performance, Emission

I. INTRODUCTION

Diesel engines a main source of heavy duty vehicles. They are intimidating environment as they are a main contributor to atmospheric pollution as it emits more HC, CO and NOx [1, 2]. These pollutants leads to acid rain and photochemical contamination Emissions can neglect by increasing the efficiency of the engine and reducing the specific fuel consumption. One the best way to reformulate the diesel by using cerium oxide nanoparticles to reduce emissions [3]. Since metal oxide nanoparticles has the ability to catalyze combustion reactions by donating oxygen atoms. Usually the catalytic activity depends on the surface area, so using Nano particles can offer distinct advantages over bulk materials [4-8]. In general, cerium has many interesting properties like hardness, high stability, high insulation and transparency. It has major applications such as fire retard, catalyst insulator, surface protective coating and composite material. Adding cerium oxide nanoparticles to diesel can help the decomposition of HC and CO [9, 10]. Thus, it reduces the amount of pollution and also reduces the amount of fuel consumption. It also noted that cerium oxide will increase pressure and heat release rate in the combustion chamber which reduces HC, CO and increases the thermal efficiency [11, 12]. In this paper, investigated the performance and emission characteristics of diesel engine using neat diesel fuel, diesel fuel using cerium oxide nano particles in different existence.

II. PROPERTIES OF NANOPARTICLES

A. X-ray diffraction pattern (XRD)

The XRD pattern of cerium oxide nanoparticles is shown in Fig. 1. The XRD pattern was scanned from 20-60 degrees with the scan rate 2θ min-1. The XRD profile established the polycrystalline nature of the cerium oxide nanoparticles. The high intensity peaks were observed at 003, 006, 009, 012 crystal planes. The diffraction peaks in these XRD spectra indicate the pure cubic fluorite structure.

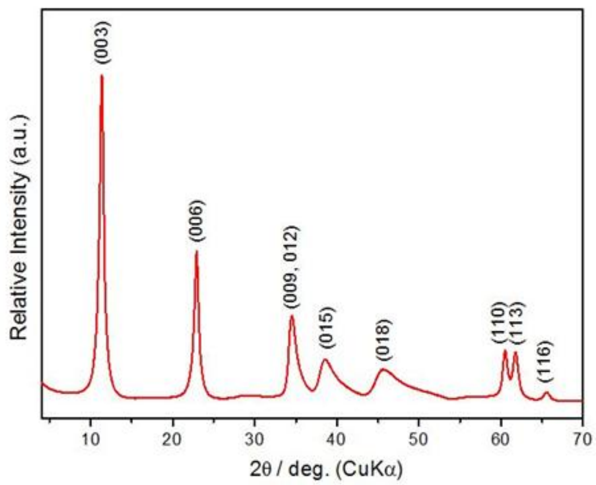

Fig. 1. X-ray diffraction pattern.

Crystallite size was obtained by using the Debye's Scherrer equation:

$$D = \frac{K}{\beta \cos(\theta)}$$

Where, K is the shape factor, λ is the X-ray wavelength, β is the line broadening at half the maximum intensity in radians and θ is the Bragg angle. The crystallite size was found to be in the range from 12-22 nm.

B. Scanning Electron microscopy (SEM)

The Scanning Electron Microscope of cerium oxide nanoparticles is shown in Fig.2. Surface and morphological characterization of CeO2 nanoparticles were carried out using scanning electron microscopy. Nano sized spherical shaped cerium oxide particles obtained was confirmed. The mean size of the particles varies from 16- 26.7 nm.

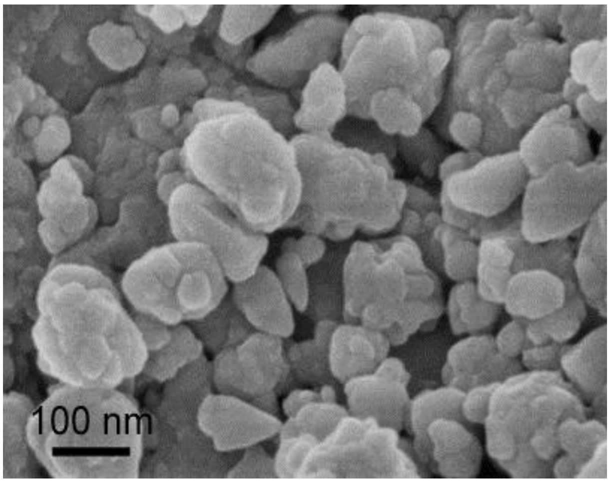

Fig. 2. Scanning Electron Microscope. Abbreviations and Acronyms.

C. Fourier transform infrared spectrography (FTIR)

The FTIR spectrum of cerium oxide nanoparticles is shown in Fig. 3. The spectrum was recorded in the wave number assortment of 400-4000 cm-1. The band at 3375.80 cm-1 represents the water and the hydroxyl stretch. The intensive band at 1334.23 cm-1 represents N-O stretch due to the existence of nitrate. The absorption band at wave number 555.84 cm-1 represents the Ce-O stretch. From the spectrography, it confirmed the formation of nanoparticles.

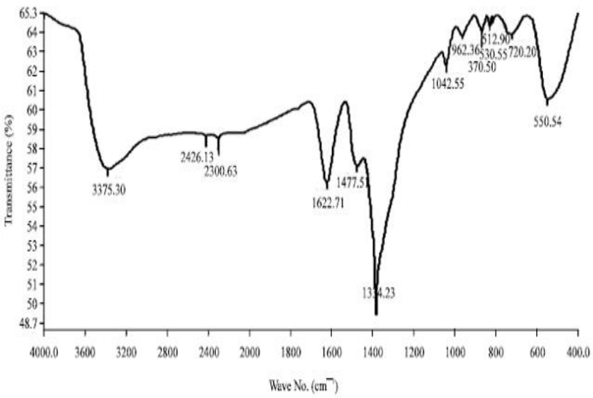

Fig. 3. Fourier transform infra-red spectroscopy.

III. PREPARATION OF FUEL BLEND

For the blending of cerium oxide nanoparticles in diesel, take samples of diesel say 1 litre and then 0.025g of cerium oxide nanoparticles is added to make the dosing level of 25 ppm. Subsequently to increase the dosing level of 50 ppm, we have to increase to 0.05g/lit respectively. After addition of cerium oxide nanoparticles it was shaken well. And then it is poured into apparatus where it is agitated for about 30 minutes in an ultrasonic shaker for making uniform suspension. It should be shaken well before use, as excess of nanoparticles settle down on solution.

IV. EXPERIMENTAL AND TEST PROCEDURE

Experiments were conducted on Kirloskar TV1, four stroke, single cylinder, air cooled diesel engine. The rated power of the engine was 5.2 kW at 1500 rpm. The engine was operated at a constant speed of 1500 rpm and a standard injection pressure of 300 bar. Details of the engine specification are given in Table 1. The fuel flow rate is obtained by the gravimetric basis and the airflow rate is obtained on the volumetric basis. The AVL smoke meter is used to measure the smoke density. AVL five-gas analyzer is used to measure the rest of the pollutants. A burette is used to measure the fuel consumption for a specified time interval. During this interval of time, how much fuel the engine consumes is measured, with the help of a stopwatch. The experimental setup is indicated in Fig. 4.

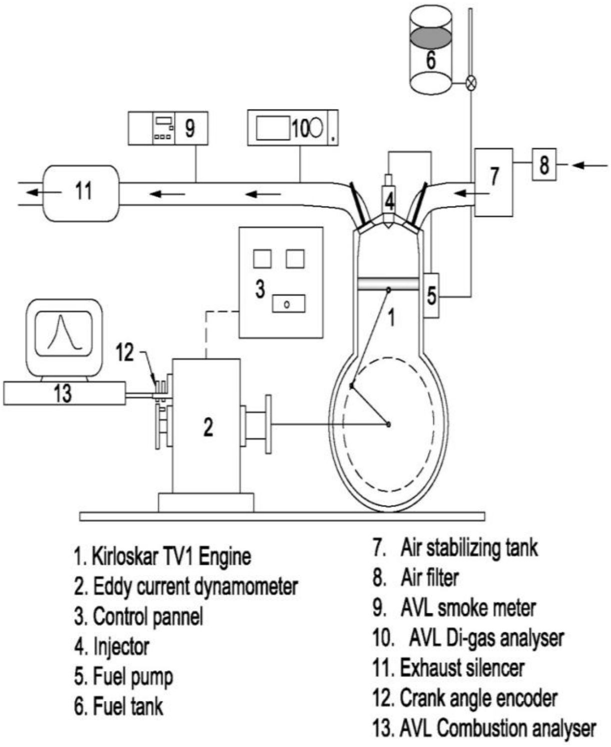

Fig. 4. Experimental Setup.

TABLE I. ENGINE SPECIFICATION

Type	:	Vertical, water cooled, four stroke
Number of cylinders	:	One
Bore	:	80 mm
Stroke	:	110 mm
Compression ratio	:	17.5:1
Maximum power	:	5.2 kW
Speed	:	1500 rev/min
Dynamometer	:	Eddy current
Injection timing	:	23 (before TDC)
Injection pressure	:	250 kgf/cm^2

V. Results and Discussion

The operation of the engine was found to be very smooth throughout the rated load, without any operational problems for the cerium oxide nanoparticles blended diesel fuel. In the present section, based on the combustion data, cylinder pressure and heat release rate are plotted against crank angle. The cerium oxide nanoparticles effectively reduce CO, HC and smoke emissions.

A. *Brake thermal efficiency (BTE)*

Fig. 5 shows the variation of brake thermal efficiency with increasing load for two different concentrations of cerium oxide nanoparticles. The BTE of the CEONP blended diesel was observed to be better, compared to neat diesel. This could be attributed due to the better combustion characteristics of cerium oxide nanoparticles. This behavior can be explained based on the additional oxygen content available in the fuel due to an increase in the nanoparticles concentration. The maximum BTE for CEONP50 is 25.9% where it is 25.2% for CEONP25 and 24.6% for neat diesel at full load.

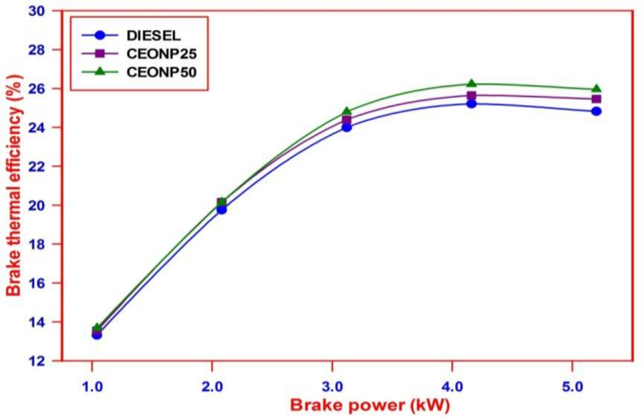

Fig. 5. Brake thermal efficiency against Brake Power.

B. *Specific fuel consumption (SFC)*

The performance tests were conducted on a DI diesel engine with diesel and modified diesel fuels. The variations of brake specific fuel consumption for the neat diesel and the cerium oxide nanoparticles blended diesel fuels at various loads have been depicted in Fig. 6. It is observed that the BSFC values of neat diesel fuel and CEONP25 fuel are nearly same, while the CEONP50 fuel shows a considerable reduction of about 9% in comparison with the other cases.

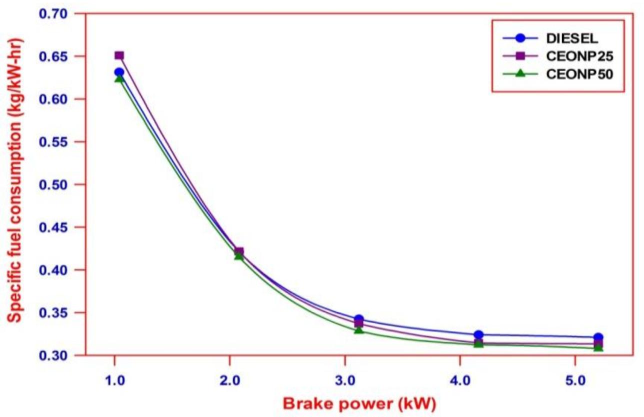

Fig. 6. Specific fuel consumption against Brake Power.

C. *Oxides of Nitrogen (NOx)*

The NOx emissions of the engine at different nanoparticles concentrations with the different engine loads have been shown in Fig. 7. It is clear that, the NOx emission radically increases, by means of CEONP nanoparticles additive. NOx emission is directly proportional to efficiency of the engine because NOx increases with combustion pressure and exhaust temperature of the engine. The additional oxygen content in the modified fuel blends increases the in cylinder combustion temperature which in turn increases the NOx emission. The NOx emission from CEONP50 is 948ppm, whereas it is 880ppm for CEONP25, compared to 850ppm for neat diesel, at the full load respectively.

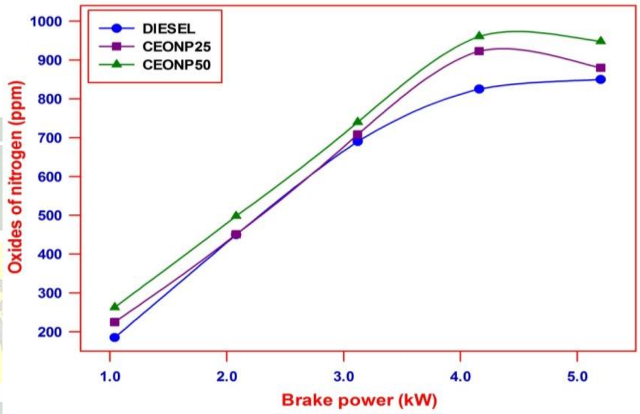

Fig. 7. Oxides of nitrogen against Brake Power.

D. *Smoke density*

Fig. 8 shows the smoke opacity percentage of diesel and modified diesel fuel at different brake power. Reduced smoke opacity is observed in the case of CEONP50. This could be attributed due to shorter ignition delay and better combustion characteristics of CEONP blended diesel fuel. The smoke opacity for CEONP50 is 44.7HSU, whereas it is 70HSU for sole diesel fuel at full load.

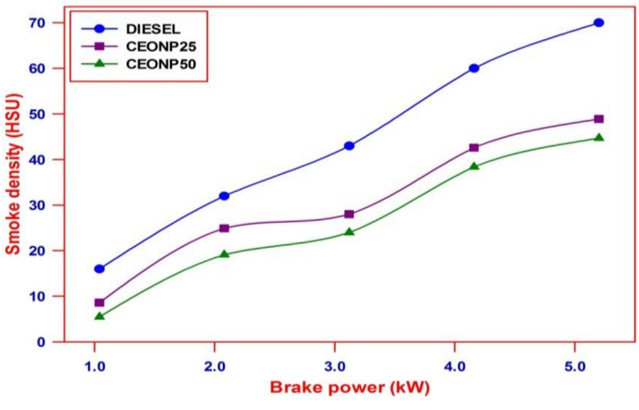

Fig. 8. Smoke density against Brake Power.

E. *Carbon monoxide (CO)*

The variation of carbon monoxide with brake power is shown in Fig. 9. The carbon monoxide emission decreases with the addition of cerium oxide nanoparticles with the diesel fuel. Generally, the CO emission is caused due to the poor mixing of air and fuel, and incomplete combustion of fuel. The CEONP present in the fuel acts as an oxygen buffer, releasing oxygen depends upon the partial pressure of oxygen for fuel combustion. The CO emission is marginal up to the brake power of 5.2 kW and then increases rapidly with full load condition. The CO emission reduced up to 26% and 21% of the cases of CEONP25 and CEONP50 fuels, respectively, at the full load of the engine.

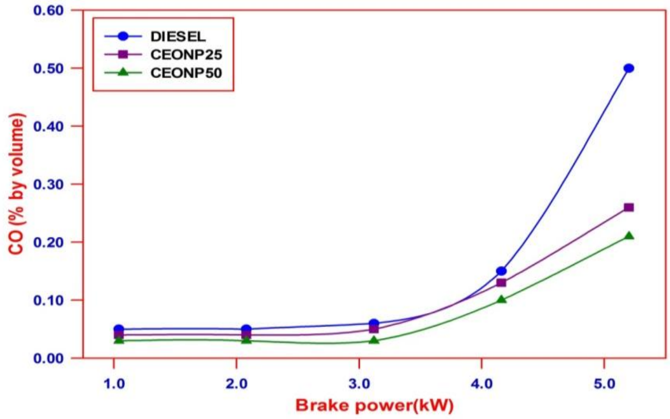

Fig. 9. Carbon monoxide emission against Brake Power.

F. *Hydrocarbon (HC)*

The unburned hydrocarbon emission from diesel and CEONP blended diesel with brake power is shown in Fig. 10. From the figure it is understood that the CEONP blended diesel produces less HC emission in comparison to that of sole diesel fuel, because of CEONP present in the diesel acts as an oxygen donating catalyst and oxidize the hydrocarbon. The least HC emission is observed as 48ppm for the CEONP50 blended diesel fuel at the brake power of 5.2kW. This is due to the higher cetane number and high oxygen content present in the CEONP blended diesel.

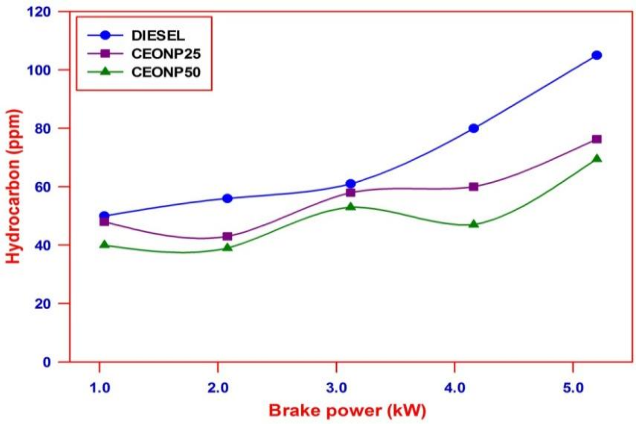

Fig. 10. Hydrocarbon emission against Brake Power.

CONCLUSION

In the present investigation, Kirloskar TV 1 engine performance, emission and combustion characteristics by using cerium oxide nanoparticles blended diesel are studied and compared the values with neat diesel. Following results can be concluded from the experimental study.

- A marginal improvement in brake thermal efficiency was observed with the use of cerium oxide nanoparticles.
- The reduction in HC emission by using cerium Oxide nanoparticles blended with diesel. CEONP50 showing 35% reduction in HC compared with neat diesel fuel.
- The nano cerium oxide additives were effective in decreasing CO emissions. CO emissions with 25ppm CEONP and 50ppm CEONP additives are decreased by 48% and by 58%, respectively
- NOx Emission dramatically increases by using CEONP blended diesel fuel compared to neat diesel fuel.
- The decrease in the emissions is proportional to the dosing level of CEONP nanoparticles in the diesel and optimum dosing level of 50 ppm of CEONP nanoparticles was observed.

Hence, cerium oxide nanoparticles are efficient in improving performance and reducing the exhaust harmful emissions from the DI diesel engine.

Nomenclature:

bmep	Brake mean effective pressure, MPa
SFC	Specific fuel consumption, kg/kWh
BP	Brake power, kW
CO	Carbon monoxide, %
HC	Hydrocarbon, ppm
NO	Nitrogen oxide, ppm
CEONP25	Cerium Oxide nanoparticles of 25ppm blended diesel
CEONP50	Cerium Oxide nanoparticles of 50ppm blended diesel
rpm	Revolution per minute
TDC	Top Dead Centre

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