Experimental investigation of cerium oxide nano-fluid emulsion fuel performance and emission characteristics on variable compression ratio diesel engine.

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ABSTRACT

The limited fossil fuel resources along with the need to reduce emissions are major impulse to the development of alternative fuel. The heavy vehicular density in big cities and different operating conditions of CI engine are the alarming problem of emissions. In recent research emulsion has been developed as an alternative fuel for CI engine. Emulsion has shown slightly lower performance and reduction in SOx, CO, HC and CO_2 as compare to diesel. But formation of NOx with Emulsion fuel was observed higher. After the advent of nanotechnology nanofuels prepared with nanoparticles has become interesting field of research topic around the world. Nanofuels have shown better improvement in combustion, performance and emission characteristics of CI engine. In this present work ***"Experimental investigation of cerium oxide nanofluid emulsion fuel performance and emission characteristics on variable compression ratio diesel engine"*** *nanofuels were prepared by adding the cerium oxide nanoparticles to the Emulsion. Nanofuels were prepared with high speed ultrasonication and mechanical agitation process to increase the stability.*

The experiments were conducted on variable compression ignition ratio single cylinder four stroke diesel engine at constant 1500 RPM to evaluate the influence of cerium oxide nanoparticles. The load and compression ratio was varied from 0 to 6 kg and 14 to 18 on the engine. Experiments were performed using neat diesel and Emulsion $E15CeO_2$ 100. The BP, BSFC, BTE, EGT, CO, NOx and HC parameters were compared to pure diesel. It was observed that cerium oxide blended Emulsion $E15CeO_2100$ considerably improve the performance parameters like Brake power by 6.09 %, Brake Thermal Efficiency by 4.83 % and Brake Specific Fuel Consumption reduced upto 9.57 % as compared to the diesel at CR 14 with full load condition. The harmful emission especially NOx using E15CeO2100 was reduced upto 32 % PPM as compared to diesel.

***Key Words**: BP, BSFC, BTE, CO and NOx*

INTRODUCTION

The role of compression ignition engine in the energy development, automobile and in industrial activities is significant. The compression ignition engine is more advantageous then the spark ignition engine in terms of reliability, responsiveness, weight, less fuel consumption and also due to low emission of harmful gases like CO, HC and NOx. Higher efficiency and brake power makes diesel engine more useful in ^{the} industrial activity and light duty automobile. Our country uses 2,50,000 barrels oil per day which rank 6^{th} in the world and the harmful effects of pollution are also assessed in past few years [1].

Pollution Conservation and Research Analysis Association (PCRA) stated that the total oil uses in the transportation sector is one half of the total oil consumption in India. The waste matter CO which is the prime harmful emission followed by the HC is mainly released by the automobiles which causes the environmental pollution. Transport sector exclusively ingests over one half of the total oil consumption within the country [1]. India produces approximately 275 tonnes of CO out of which 95% contributed by the transport sector [2].

The pollution in air causes the severe impact on the human health as in a day healthy people inhale 35 lbs of air [3]. Due to poor quality range of air in atmosphere raises the health issues from simple symptoms of eyes irritation to the significant health issues like defective operation of respiratory organs, weakened the immune power which resists the imperfection within the body, lung cancer, congenital disabilities and premature death chiefly because of metabolic process and cardiovascular disease [2, 4].

Conventional fuels are found rather inadequate in rising emission characteristics that is the initial essential stage for implementation of preventive emission regulation. Use of nanofluids could decrease the emission parameter and can improve combustion efficiency by enhancing the ignition delay and fuel properties. Nanofluids had the potential because of the next-generation fuel for lowering emission and improving combustion efficiency. Though nanofluids have displayed tremendously exciting potential applications, some crucial hinders also exist before the commercialization use of nanofluids.

EMULSIONS TECHNOLOGY

The combination of microscopic or ultramicroscopic size droplets of two different liquids distributed throughout in each other is known as Emulsion. Emulsions are made by the mechanical approach or by a way of impulsive constituents. In case of spontaneous emulsions, the blending is spontaneous and straightforward. However, if the two liquids are not blend properly, then a different chemical referred to as a surfactant agent is employed to tie the molecules of the ingredient liquids. Emulsion are created by mixing the different liquid blends, using mechanical agitator for a short span of time

IMPORTANCE OF EMULSION IN IC ENGINE

The reason behind the development of water diesel emulsion is the environment consideration and the day by day increase in harmful emission. Nitrogen oxide including NO and NO2 shown considerable reduction in harmful emission after using the water based diesel emulsion. For the better combustion of fuel, emulsion (water diesel emulsion) shows lot of improvement due to small size water droplets dispersed in oil. Emulsion fuel uses different fuel additives together with the triglycerides and Hydrocarbons. The main reason behind the thought of development of emulsion is the diesel fuel, which produces high temperature and pressure inside the cylinder. The use of emulsion as a fuel decreased the high temperature inside the cylinder by the evaporation of water. The improved result of using water diesel emulsion includes:

•Improvement in the brake power

•reduction in the specific fuel consumption

•reduction in the harmful exhaust emission

STRUCTURE OF NANOFLUIDS

These are tiny particle (below 100nm) like polymeric compound, non metallic and metallic incorporated with standard fluid which further helps in the removal of heat and improves the heat transfer rate within the cylinder. A solid like structure is produced near to the nanoparticles solid surface at the bottom of fluid particles. Nonolayer act as a thermal viaduct between the solid nanoparticles and liquid base fluid and thus improve the thermal conductivity. A structural description of nanoparticles shown in figure 1.1

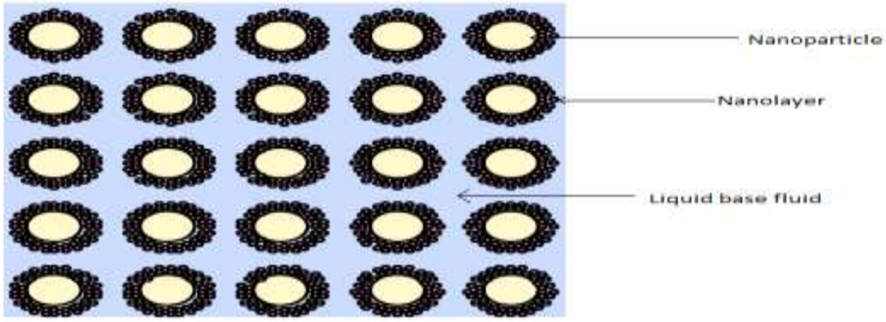

Figure 1.1: Nano particles Structure

PRODUCTION OF WATER-DIESEL EMULSION OIL

The Cerium oxide nanoparticle purchased from XINYU ADVANCED MATERIALS LIMITED, CHINA was chosen to assess the impact on water-diesel emulsion oil for the research. Mechanical agitator, water-diesel emulsion oil and ultrasonicator were employed for the intermixing to prepare the blend. Steps used in the production of nanoparticle blended water-diesel emulsion oil are detailed below:

• To begin with, ultrasonication is employed to disperse the cerium oxide nanoparticle (100 P.P.M.) within the water for 90 minutes within the beginning. In order to integrate the prepared Nanofluids with diesel, a combination (2% by vol.) of two non-ionic surfactant span 80 and tween 80 was ready by surfactant, with hydrophilic and lipophilic balance value 8.

•In the second step, the neat diesel oil (83% by vol.) is integrated with surfactant mixture and agitated by means that of mechanical agitator for 15 minutes at a constant speed of 2500 r.p.m. simultaneously; the cerium oxide Nano fluid (15% by vol.) is added with the help of a metering pump. The resultant product is that the water-diesel emulsion fuel ($E15CeO_2$ 100).

Figure 1.2: Surfactant for emulsion fuel **Figure 1.3: Surfactant mixture for emulsion fuel**

EQUIPMENT USED FOR ENGINE PERFORMANCE PARAMETRS

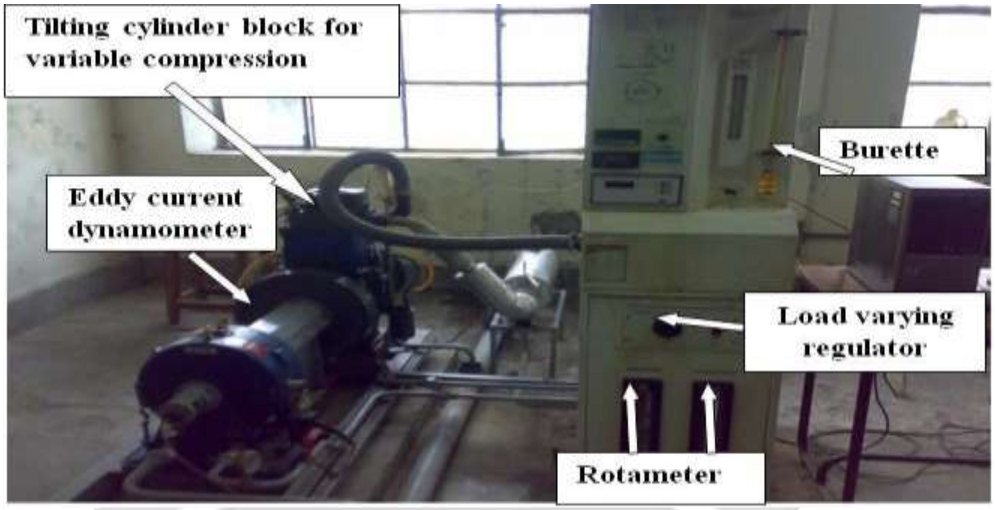

Figure 1.4: Single cylinder four stroke, variable compression ignition engine

Specifications of the engine

The experiments were done on variable compression ratio engine. Specifications are as following:

Table 1.1: Specification of variable compression ratio engine

Engine Type	Single Cylinder 4-Stroke, Water Cooled diesel engine
Make Type	Kirloskar
Bore	87.5 mm
Stroke	110 mm
Connecting rod length	234 mm
Rated power	3.75 kW@1500 R.P.M
CR	Range from 12-18
Orifice diameter	20 mm
Dynamometer arm length	145 mm
Cooling media	Water cooled
Load indicator	Range 0-50 Kg, Supply 230V AC, Digital
Load sensor	Load cell, type strain gauge, range 0-50 Kg
Loading device	Eddy current dynamometer
Rotameter	Engine cooling 40-400 LPH; Calorimeter 25-250 LPH
Temperature sensor	Thermocouple, Type K
Speed indicator	Digital with non contact type speed sensor

Equipment used for the evaluation of engine emissions

Horiba analyzer was used to determine the HC. Flue gas analyzer was used to evaluate the CO and NOx of the engine.

Figure 1.5: Horiba analyzer

Figure 1.6: Flue gas analyzer

RESULTS AND DISCUSSIONS

Results are shown with the help of graphs and discussion for different reasons behind the results. To evaluate the emission characteristics and performance parameters of diesel and E15CeO_2 100, the experiments were conducted on the variable compression ratio engine. The experimental results are discussed in the following steps:

Step I: Performance parameters were described.

Step II: Emission characteristics were discussed.

BRAKE POWER

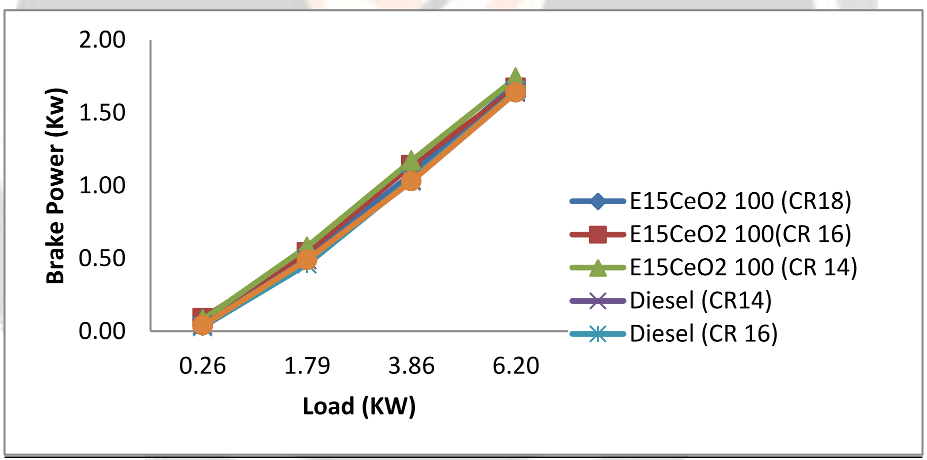

Figure 1.7: Brake power variation with respect to load for Diesel & E15CeO_2 100 at compression ratio 14, 16 and 18

Impact of CR on engine brake power

Engine brake power variation at CR 14, 16 and 18 with respect to load for optimum E15CeO_2 100 is shown in figure 1.7. It was observed that E15CeO_2 100 at compression ratio 14 with full load condition produces the maximum brake power. This is due to the complete combustion of fuel inside the cylinder. Due to better combustion and atomization of fuel, complete conversion from chemical to mechanical energy takes place which is further attributed to higher brake power [6]. Addition of nanoparticles help to remove the carbon deposit on the cylinder wall which results in reduces the frictional losses may be the reason for higher brake power [5].

BRAKE THERMAL EFFICIENCY

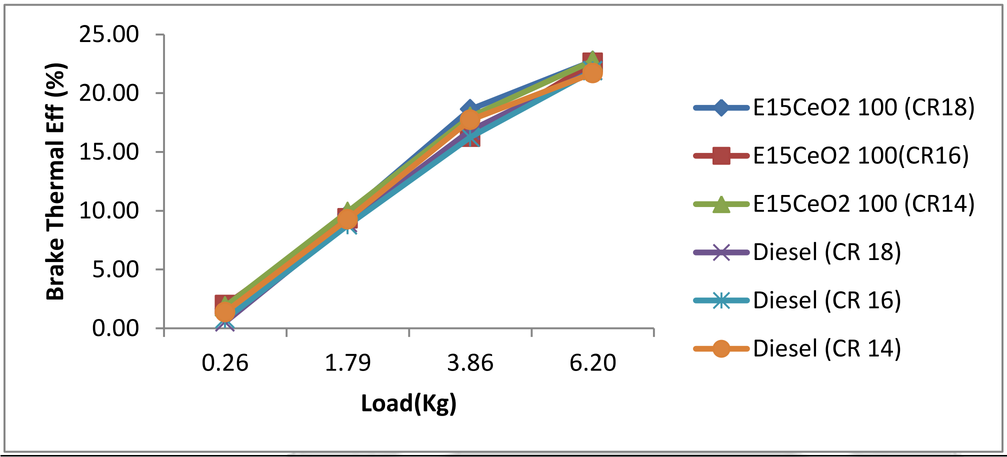

Figure 1.8: Brake thermal efficiency Variation with respect to load for diesel & E15CeO$_2$ 100 at compression ratio 14, 16 and 18

Impact of CR on Brake thermal efficiency

Maximum BTE 22.75% was obtained at full load and compression ratio of 14 for E15CeO$_2$ 100. The minimum BTE was 21.70% obtained at compression ratio 14 for diesel. Higher BTE at compression 14 could be attributed to the better combustion and better intermixing of the fuel with air [6]. One more reason was observed for the higher BTE was lower BSFC and better Brake Power at compression ratio 14.

BRAKE SPECIFIC FUEL CONSUMPTION

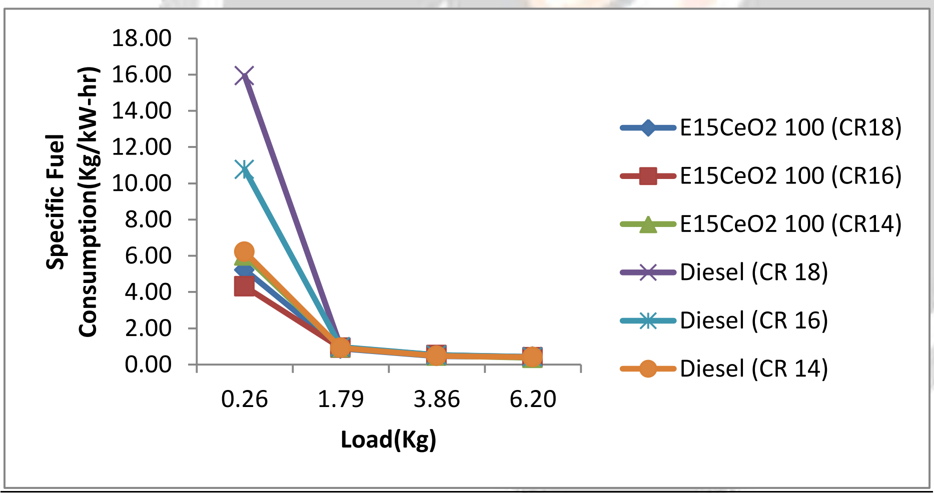

Figure 1.9: BSFC Variation with respect to load for Diesel and E15CeO$_2$ 100at compression ratio 14, 16 and 18

Impact of CR on brake specific fuel consumption

It was observed from the results that with increase in CR from 14 to 18, brake specific fuel consumption also shows increasing trends. Brake specific fuel consumption found to be lowest at CR 14 as compared to CR 16 and 18 because at higher compression ratio, the fuel charge gets diluted. The value of BSFC observed as lowest at compression ratio 14 and at full load condition for E15CeO$_2$ 100 as compared to diesel. Variation in BSFC at full load and compression ratio 14, 16 and 18 are illustrated in figure 1.9.

EMISSION CHARACTERSTICS

NOx

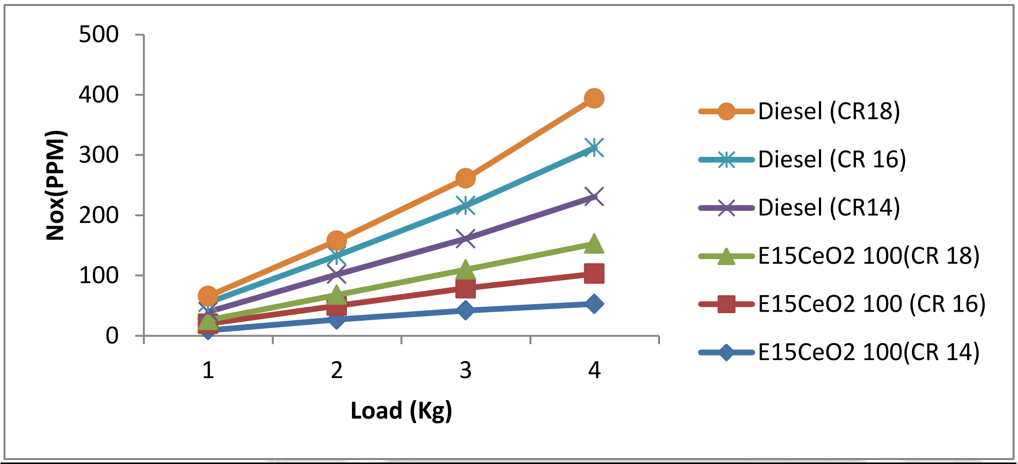

Figure 1.10: NOx Variation with respect to load for E15CeO$_2$ 100 and diesel at compression ratio 14, 16 and 18

Impact of CR on NOx emission

It is observed by the test results that with the increase in CR from 14 to 18 the content of NOx emission also increases. From the figure 1.10 it is clear that E15CeO$_2$ 100 blend exhibited least value of NOx emissions. This is mainly due to the higher combustion chamber temperature which increased as the compression ratio increased due to lower ignition delay. Secondly this was happened due to higher temperature achieved by the blend due to complete combustion and with the addition of CeO2 nanoparticle prevents the carbon deposition on the cylinder wall and improving the heat transfer co efficient through cylinder wall which further decreases the content of NOx emission for E15CeO$_2$ 100. NOx Variation with respect to load of E15CeO$_2$ 100 at compression ratio 14, 16 and 18 is illustrated in figure 1.10.

CONCLUSION

The objective of present study is to investigate the effect of cerium oxide nanoparticles in the concentration of 100 PPM on the diesel blends. The nanoparticle added diesel blends were charged in variable compression ignition engine. The overall investigation of this work based on the manufacturing, performance and emission characteristics of different blends of diesel with and without nanoparticles were carried out. On the basis of present work conclusion can be described as following:

Optimum compression ratio: The results were concluded at full load based on the experimental data:

- Brake power and Brake thermal efficiency were observed higher at compression ratio 14 for E15CeO$_2$ 100
- Minimum brake specific fuel consumption was observed at compression ratio 14.
- Lowest NOx emission was observed at compression ratio 14, 16 and 18.

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