RESEARCH ARTICLE

BULLETIN OF SCIENTIFIC RESEARCH

DOI: 10.34256/bsr1926

Influence of Nano Fuel Additives to Control Environmental Pollution from Naturally Aspirated Di-Ci Engine

R. Prakash [a, *], A. Murugesan [b], A. Kumaravel [b]

[a] Assistant Professor, Department of Mechanical Engineering, K.S.Rangasamy College of Technology, Tiruchengode, Namakkal, Tamil Nadu, India.

[b] Professor, Department of Mechanical Engineering, K.S.Rangasamy College of Technology, Tiruchengode, Namakkal, Tamil Nadu, India.

*Corresponding Author:prakashr@ksrct.ac.in DOI: https://doi.org/10.34256/bsr1926

Received: 25-09-2019
Accepted: 14-11-2019

Abstract: Diesel fuel is necessary for farming, transport, and industrialized sector. It contributes to the wealth of the universal economy while it is widely used due to having higher flexibility, combustion efficiency, consistency and handling facilities. However, emissions from fossil fuel are considered as the main source of environmental pollution. Thus, it becomes necessary to reduce emission by improving the performance of the engines. Recently the addition of catalytic material like nanoparticles to diesel proves to be a hopeful solution to reduce emission without much modification of the existing engine design. In the present study, the influence of nanoparticles doped with diesel on the performance and emission characteristics are carried out in a naturally aspirated, single-cylinder, four-stroke, water-cooled, 3.7 kW, direct-injection compression-ignition engine is coupled with eddy current dynamometer and high-speed data acquisition system. Cerium Oxide nanoparticles are selected as the best oxygen boosting catalytic nanoparticle and it is prepared by the sol-gel process. Nanoparticles, then doped with diesel with the help of an Ultrasonicator with different molar concentrations (5 ppm, 7.5 ppm, 10 ppm, 15 ppm). Fuel properties of nano doped fuel samples are tested and presented in this paper. The DI CI engine experimental results were found to be brake thermal efficiency is increased by 3.6% by simultaneously reducing fuel consumption by 3.63% and also harmful environmental pollution like carbon monoxide, unburned hydrocarbon, carbon dioxide, and smoke level are decreased by 9.11%, 6.3%, 3.12%, and 12.6% respectively compared to pure diesel. It may be due to the enhanced surface to volume ratio, catalytic activity and improving the mixing rate of fuel and air in the combustion chamber.

Keywords: Diesel engine, Nanoparticles, Cerium Oxide, Ultrasonicator, Environmental pollution, Data Acquisition system.

1. Introduction

Vehicular pollution has grown at an alarming rate due to rising urbanization in India. Air pollution from vehicles in metropolitan areas has become a severe problem. The pollution from vehicles has begun to tell through symptoms like cough, headache, nausea, irritation of eyes, various bronchial and visibility problems. The main pollutants emitted from automobiles are hydrocarbons, lead/benzene, carbon monoxide, sulphur dioxide, nitrogen dioxide and particulate matter [1].

The other factors of vehicular pollution in the urban areas are two-stroke engines, poor fuel quality, old vehicles, inadequate maintenance, congested traffic, poor road condition and old automotive technologies [2].

There are several ways to reduce vehicular emissions practically. Some of the ways for reducing them are like burning fewer fuels, burning cleaner fuel, etc., but these methods involve hardships to the human race but beneficial for the environment.

Nan particles as a fuel additive are emerging owing to its high surface area to volume ratio, oxidation capacity, and thermal conductivity when dispersed in any base fuel. These nanoparticles doped improve properties of fuel and promote complete combustion that improves the performance of the engine as well as reduces exhaust emissions. Addition of the nano additives to diesel fuel causes a decrease in particulate emissions, decrease in the oxidation temperature and increase in NO_x emission [3, 4]

Sajith V (2010) observed the addition of aluminium oxide reduces Brake Specific Fuel Consumption (BSFC), because of the presence of aluminum oxide oxidizes carbon deposit from engine cylinder wall leading to a smooth and better engine performances were observed with appreciable reduction of hydrocarbon and NOx emission levels due to the boost of high oxygen concentration when Al_2O_3 – diesel blends compared with the neat diesel [5].

Swaminathan M.R (2013) studied that brake thermal efficiency was increased marginally by 4% from the conventional diesel fuel with the addition of MnO and CuO. Also, there was a significant reduction was observed in HC, CO and NOx emission with MnO+diesel and CuO+diesel. In addition, performance with MnO+diesel was slightly better than CuO+diesel for its Van der Waals bonding of molecules with oxygen [6].

TayfunOzgur (2015) has studied the effect of NOx emissions on diesel-fuelled compression ignition engine with different nanoparticle additives like aluminium oxide (Al_2O_3), magnesium oxide (MgO), titanium oxide (TiO_2), zinc oxide (ZnO), silicon oxide (SiO_2), Iron oxide (Fe_2O_3), nickel oxide (NiO), nickel-iron oxide ($NiFeO_4$) and also the nickel-zinc iron oxide ($ZnO.5NiO.5Fe_2O_4$) [7].

Sunilkumar T (2017) studied that improvement in the calorific value, reduction in flashpoint, higher enhancement in the Brake Thermal Efficiency (BTE) and reduction in the harmful pollutants for the blend of graphene nanoparticles due to the incorporation of graphene nanoparticles give more surface area for reactivity and having higher thermal conductivity were observed [8].

Krinal N Gajera (2018) has done a review study on the effects of addition of various nanoparticles on performance and emission properties of compression ignition engine with diesel blends as a fuel [9].

With a huge number of references from numerous journals, concludes that many chemical nanoparticles were used for improving the engine performance, and exhaust emissions. When diesel is doped with oxide nanoparticles like Aluminium oxide, magnesium oxide, and silicon oxide, they exhibit many disadvantages equal to advantages but when Cerium Oxide chemical nanoparticle is blended with diesel, they exhibit more advantages with very few disadvantages only. The objective of the present study is to prepare the cerium oxide nanoparticle from the sol-gel process doped with neat diesel and investigate the performance and emission characteristics of a naturally aspirated DI-CI engine.

2. Preparation of Test Fuels

2.1. Preparation of cerium oxide nanoparticle synthesis

There are several instruments and devices which are used for the synthesis of nanoparticles by sol-gel method. The cerium oxide nanoparticles are obtained from precursors of cerium nitrate hex hydrate and sodium hydroxide [5].

The systematic procedure of the synthesis of cerium nanoparticles are explained as follows

I. 0.1M of cerium nitrate hex hydrate and 0.3M of sodium hydroxide is weighed using a digital balance of accuracy 1 mg.
II. Prepare 1 liter of double distilled water and add one 0.1M of cerium nitrate hex hydrate in it.
III. Place the beaker containing double distilled water along with cerium nitrate hex hydrate in a magnetic stirrer.
IV. Add 0.3M of sodium hydroxide pellet by a pellet in double-distilled water in order to maintain the pH level of 8.
V. After two hours of constant stirring at 1000 rpm and constant heating at 80°C, the solution is kept to cool down.
VI. Then the solution is kept in a centrifuge for enabling purity in the final product.
VII. The gel obtained is then heated in a hot air oven at 80°C to take away the moisture content in the gel. The powder is again heated in a muffle furnace at 270°C for 3-4 hours for chemical stability and the cerium oxide nanoparticles are obtained.

3. Fuel Preparation

Ultrasonicator is a device used for uniform dispersing nanoparticles in diesel. In a beaker, one liter of diesel is taken and then 1gram of cerium oxide nanoparticles is added. After the addition of cerium oxide nanoparticles, it is allowed into a mechanical homogenizer apparatus where it is agitated for about 30 minutes in an ultrasonic vibrator making uniform dispersion. It is always taken in care, shaken well before use because maybe settling down the excess of nanoparticles on the solution.

2.2 Fuel Properties

The fuel properties of prepared fuel blends are compared with diesel based on viscosity, calorific value, density, flash point, and fire point. The fuel properties are presented in table 1.

3. Experimental Setup and Procedure

A stationary naturally aspirated, single-cylinder, four-stroke, 3.7 (5 HP), water-cooled, variable compression ratio, I-CI engine coupled with data acquisition system was used in this experimental investigation.

Table 1. Fuel properties of samples

Properties	Diesel	Diesel + 5ppm C_eO_2	Diesel + 7.5 ppm C_eO_2	Diesel + 10 ppm C_eO_2	Diesel + 15 ppm C_eO_2
Kinematic Viscosity at 40°C (cSt)	2.5	2.7	2.18	2.64	3.12
Calorific value(MJ/Kg)	43.8	43.6	43.2	43.2	43.1
Density (Kg/L)	0.832	0.831	0.818	0.810	0.807
Flash point(°c)	56	58	58	59	61
Fire Point(°c)	60	61	62	62	64

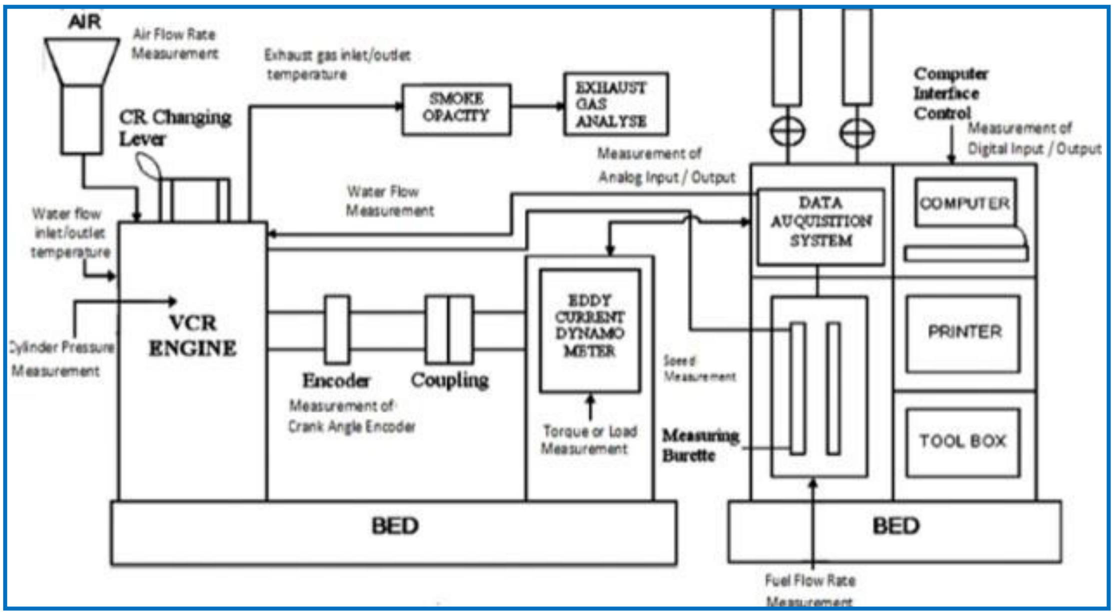

Figure. 1 Schematic representation of VCRDI-CI engine

The Schematic representation of VCRDI-CI engine is shown in Figure 1. The experiments were conducted under four different part-load and full load conditions of 0 kW, 0.78 kW, 1.45 kW, 2.84 kW, and 3.49 kW respectively using eddy current dynamometer maintained at a constant speed of 1500rpm. The exhaust emissions characteristics like CO, UHC, CO_2, NO_X, and Smole levels were measure using AVL-444 DI gas analyzer and AVL 437 Smoke meter. The engine was tested at each load conditions with diesel, diesel doped with cerium oxide nanoparticles of different proportions of 5ppm, 7.5 ppm, 10 ppm, 15 ppm respectively.

4. Results and Discussion

4.1. Brake Thermal Efficiency (BTE)

The variations of brake power Vs Brake Thermal Efficiency (BTE) with neat diesel, diesel doped with cerium oxide nanoparticles of different proportions of 5ppm, 7.5 ppm, 10 ppm, 15 ppm are shown in Figure 2. The brake thermal efficiency is a function of the engine factor, which indicates how capably the fuel energy is converted into mechanical output. The brake thermal efficiency increases with increase in loads for all tested fuels. It is seen from the graph that diesel doped with nanoparticles show a major increase in BTE when compared with neat diesel.

It is seen that the diesel doped with 10 ppm cerium oxide nanoparticles shows an increase in 3.6% BTE compared with neat diesel. Diesel doped with 10 ppm cerium oxide nanoparticles is regarded as the best optimum one. The brake thermal efficiency of the diesel doped with nanoparticles is increased due to cerium oxide is rich in oxygen and have better spray characteristics combined with the higher surface to volume ratio allows more amount of fuel to react with air to enhance the brake thermal efficiency, good spray properties, lower viscosity, and optimum calorific value. Other reasons were found to be the nano doped giving rise to high calorific value. [10, 11].

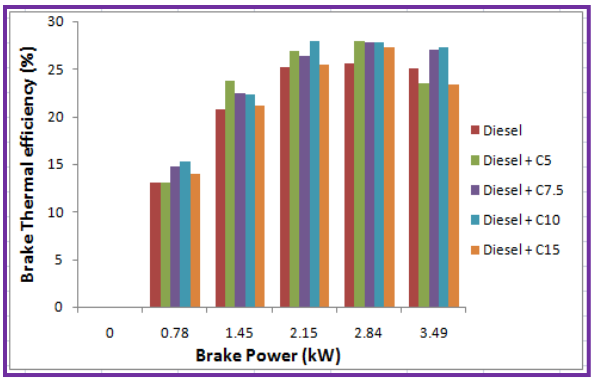

Figure.2 Variation of Brake power Vs Brake Thermal Efficiency

4.2 Fuel Consumption

The variations of Brake Power Vs fuel consumption with neat diesel, diesel doped with cerium oxide nanoparticles of different proportions of 5ppm, 7.5 ppm, 10 ppm, 15 ppm are shown in Figure 3.

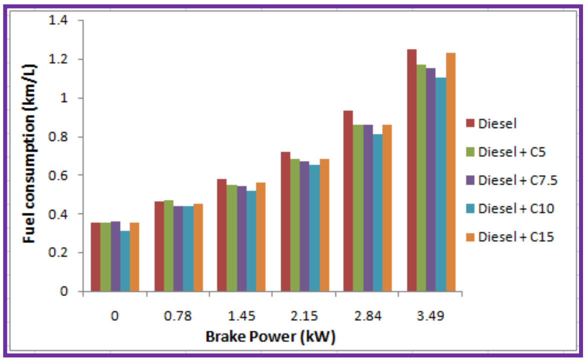

Figure.3 Variation of Brake power Vs Fuel consumption

It is seen from the above graph that fuel consumption of diesel doped with cerium oxide nanoparticles of different molar mass is less when compared to diesel. This indicates the complete combustion of fuel due to the high oxygen catalytic boosting nature of cerium oxide nanoparticles [12].

It is found that fuel consumption is reduced by about 3.63% for diesel doped with cerium oxide nanoparticles of molar concentration 10 ppm. This proves that cerium oxide nanoparticles are having high oxygen boosting capacity that allows for complete combustion of the fuel, giving rise to less usage of fuel [13].

Nevertheless, the molar concentration of 10 ppm shows best and comparatively low fuel consumption.

4.3 Carbon Monoxide (CO)

The variations of Brake Power Vs carbon monoxide emission from the fuels such as neat diesel, diesel doped with cerium oxide nanoparticles of different proportions of 5ppm, 7.5 ppm, 10 ppm, 15 ppm are shown in Figure 4.

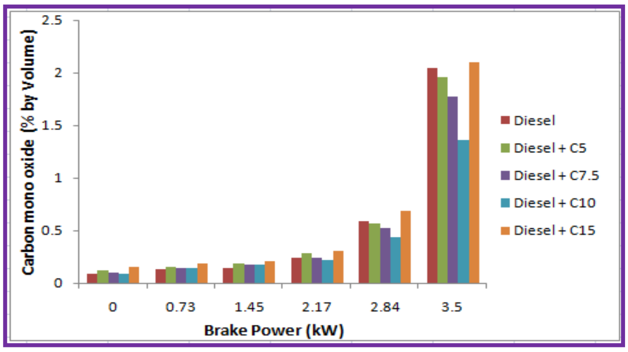

Figure.4 Variation of Brake Power Vs Carbon Monoxide emission

Carbon monoxide is produced from the partial oxidation of carbon-containing compounds. Generally, in the combustion process, carbon dioxide is formed after combustion. However, when there is not enough oxygen for the combustion process, carbon monoxide is formed and that is said to be incomplete combustion [14].

From the graph, it is seen that neat diesel produces more carbon monoxide and the diesel doped with cerium oxide nanoparticles of different molar concentration were comparatively lower to neat diesel due to the oxygen boosting catalytic nature of the cerium oxide particles. This may be due to high viscosity and slighter increase in the value of specific gravity of the neat diesel [15].

The CO emission level of nano diesel is found to be decreased by 9.11% due to the complete combustion. It also has a higher surface area to volume ratio that allows more amount of air to react with air and with the lean mixture, thus reducing the carbon monoxide emission.

Thus, from the above graph, diesel doped with cerium oxide nanoparticle of molar concentration 10 ppm is emitted very less percent of carbon monoxide compared to other nanoblend concentration.

4.4 Unburned Hydrocarbon (UHC)

The variations of Brake Power Vs Unburned hydrocarbon emission from the fuels such as neat diesel, diesel doped with cerium oxide nanoparticles of different proportions of 5ppm, 7.5 ppm, 10 ppm, 15 ppm are shown in Figure 5.

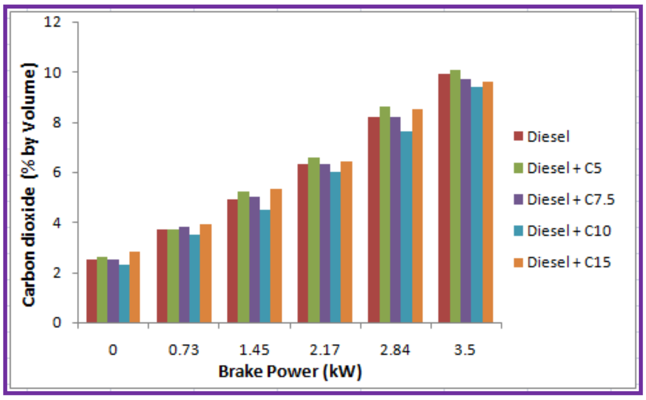

Figure. 5 Variation of Brake Power Vs Unburned hydrocarbon

It is seen from the graph that hydrocarbon emission of the diesel doped with cerium oxide nanoparticles of different molar concentration are lower in partial load, but increase at higher load. This is due to the availability of relatively less oxygen for the reactor when more fuel is injected into the cylinder at higher loads.

It is seen that the diesel doped with cerium oxide nanoparticles of molar concentration 5 ppm and 15 ppm are closer to neat diesel but in a decreased rate. This is because of the fact that the cetane number of diesel doped with nanoparticles is higher than that of neat diesel. The effects of a shorter delay period combined with oxygen boosting catalytic nanoparticles result in better combustion simultaneously reducing the HC emissions [13]. Hydrocarbon emission for diesel doped with cerium oxide nanoparticles of molar concentration 10 ppm is decreased by 6.3% at the maximum peak load. This is completely due to the perfect mixing of fuel with air and increased oxidation properties and high surface to volume ratio [15].

4.5 Carbon dioxide (CO_2)

The variations of Brake Power Vs carbon dioxide emission from the fuels such as neat diesel, diesel doped with cerium oxide nanoparticles of different proportions of 5ppm, 7.5 ppm, 10 ppm, 15 ppm are shown in Figure 6.

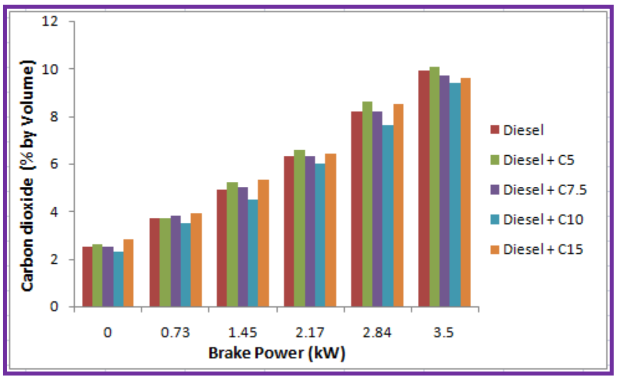

Figure.6 Variation of Brake power Vs Carbon dioxide

It is seen from the graph that CO_2 emission is increased steadily with the increase in load for neat diesel. It is also observed from the experimental values that carbon dioxide emissions were low for neat diesel when compared with diesel doped with cerium oxide nanoparticles of higher molar concentration due to complete and sometimes-excess combustion.

It is also noted that carbon dioxide emission of diesel blended with cerium oxide nanoparticles of molar concentration 10 ppm is decreased by 3.12% when compared with neat diesel. All nano blended fuels show very close values to neat diesel due to its lower carbon content and have a lower elemental carbon to hydrogen ratio than diesel fuel [16].

4.6 Oxides of Nitrogen (NOx)

The variations of Brake power Vs Oxides of nitrogen (NOx) emission from the fuels such as neat diesel, diesel blended with cerium oxide nanoparticles of different proportions of 5ppm, 7.5 ppm, 10 ppm, 15 ppm are shown in Figure 7.

NOx formation is fully dependent on the combustion temperature varies linearly with its increasing load. As the load increases, the overall fuel-air ratio increases and then the temperature increases in the combustion chamber that leads to NOx emission.

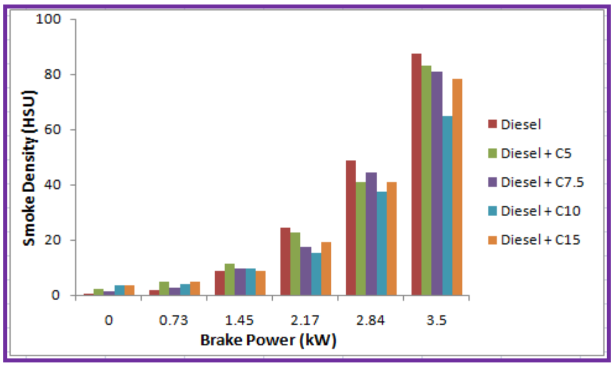

Figure.7 Variation of Brake Power Vs Oxides of nitrogen (NOx)

It is seen from the graph that neat diesel has lower NOx emissions compared to the diesel blended with cerium oxide nanoparticles of different molar concentration due to the increase in combustion temperature whereas there is an increase in the amount of fuel burned with the load. NOx emission in diesel blended with C15 is higher due to excess oxygen boosting catalytic nature beyond a limit, the high viscosity that gives poor atomization and lowers combustion temperature [17].

It is seen from the graph that at high load, the NOx emission is increased because of faster-premixed combustion result for an increase in-cylinder temperature. The minimum NOx emission is detected for neat diesel at low load conditions.

The NOx of nano-blended diesel is higher due to its oxygen boosting catalytic nature supporting the complete combustion of the fuel and increases the combustion chamber temperature simultaneously increasing the NOx emission.

Thus, the increase in NOx emission for diesel blended with cerium oxide nanoparticles of molar concentration 10 ppm by 9.31% compared with neat diesel.

4.7 Smoke

The variations of Brake Power Vs smoke emission from the fuels such as neat diesel, diesel blended with cerium oxide nanoparticles of different proportions of 5ppm, 7.5 ppm, 10 ppm, 15 ppm are shown in Figureure 8.

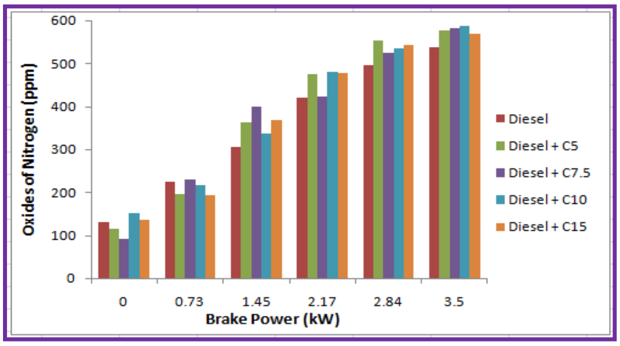

Figure.8 Variation of Brake power Vs Smoke (HSU)

It is seen clearly from the graph that smoke increases with an increase in load; also neat diesel emits more smoke when compared with diesel blended with cerium oxide nanoparticles of different molar concentration. This is due to the low viscosity of diesel as well as oxygen present in the molecules decrease the rate of combustion by increasing the smoke level when compared with nano-blended fuels [18].

The smoke emission is mainly due to the higher viscosity and lower volatility that results in poor mixture formation in which neat diesel was used in DI-CI engine. The smoke emissions of nano additive fuel blends are lower than the neat diesel due to the shortened ignition delay, higher surface to volume ratio that results in perfect mixture formation, quick evaporation rate and improved ignition characteristics of nano additives [19].

The smoke level from diesel blended with cerium oxide nanoparticles of molar concentration 10 ppm has decreased by 12.6% when compared with the smoke emissions of neat diesel.

5. Conclusion

The fuel properties, performance and emission characteristics of diesel doped with cerium oxide nanoparticles of different molar concentration like 5 ppm, 7.5 ppm, 10 ppm, and 15 ppm were investigated in a single cylinder, constant speed, naturally aspirated, variable compression ratio, DI-CI engine. Based on the experimental results, the following conclusions were made.

- Diesel doped with nanoparticles shows slightly reduced calorific value than neat diesel that helps in reducing unwanted combustion.
- From the testing of fuel properties, it is seen that the flash and fire point of the diesel doped with nanoparticles increases to assure safety for using the fuel.
- The nanoparticle doped with diesel C10 ppm lead to good improvement in brake thermal efficiency about 3.6% lowering fuel consumption by 3.63%.
- According to the experimental investigation of emission characteristics, the carbon monoxide emission is reduced by 9.11% in diesel doped C10 ppm due to complete combustion.
- This investigation also concluded that hydrocarbon emission from diesel doped with C10 ppm also showed a decrease in 6.3% due to high oxygen boosting nature.
- This study gave a settlement for diesel blended with C10 for carbon dioxide emission by 3.12% by enhancing combustion.
- Smoke emission has greatly reduced in this experimental investigation by 12.6% compared to neat diesel.
- Thus diesel blended with cerium oxide nanoparticles of molar concentration 10 ppm (C10) is well suited as a fuel additive for the diesel engine and acts environmentally friendly.

References

[1] T. Chouhan, (2017) Vehicular pollution in India - Automotive electronics: A detailed study, Accessed from: https://www.automotivelectronics.com/vehicular-pollution-india/.

[2] S. Chand, (2018) Vehicular Pollution in India (2118 Words), Accessed from: http://www.yourarticlelibrary.com/pollution/vehicular-pollution-in-india-2118-words/19796

[3] J.A. Caton, W.P. Ruemmele, D.T. Kelso, W.R. Epperly, Performance and Fuel Consumption of a Single-Cylinder, Direct-Injection Diesel Engine Using a Platinum Fuel Additive, *SAE Transactions*, (1991).

[4] Z. Chlopek, A. Darkowski, L. Piaseczny, The Influence of Metalloorganic Fuel Additives on CI Engine Emission, *Polish Journal of Environmental Studies*, 14 (2005) 559-567.

[5] V. Sajith, C.B. Shobhan, G.P. Peterson, Experimental Investigations on the Effects of Cerium Oxide Nanoparticle Fuel Additives on Biodiesel, *Advances in Mechanical Engineering*, 2 (2010) 333-338.

[6] S. Naramsetty, V.R. Kumar, Y.V. Hanumantha Rao, Performance and Emission Characteristics of Diesel Engine Fuelled with Biodiesel of Mahua Oil & Diesel Blends with Additives, *International Journal of Engineering Research and Applications*, 3(2013) 936-941

[7] Tayfun Ozgur, Xiaolu L, Hongyan C, Zhiyong Z and Zhen H, Study of combustion and emission characteristics of a diesel engine operated with dimethyl carbonate, *Energy conversion and Management*, 47 (2006) 1438-1448.

[8] S. Gumus, H. Ozcan, M. Ozbey, B. Topaloglu, Aluminium oxide and copper oxide nanodiesel fuel properties and usage in a compression ignition engine, *Fuel*, 163 (2016) 80-87.

[9] S.Ch. Rao, M. Srinivasa Rao, Performance Analysis of DI Diesel Engine Fuelled with Diesel along with Nano Additives, *International Journal of Engineering Trends and Technology*, 24 (2015) 107-110.

[10] A.Lif, K. Holmberg, Water-in-diesel emulsions and related systems, *Advances in Colloid and Interface Science*, 231-239.

[11] A.H. Lenin, R. Ravi, K. Thyagarajan, Performance Characteristics of a Diesel Engine Using Mahua Biodiesel as Alternate Fuel, *Iranica Journal of Energy & Environment*, 4 (2013) 136-141.

[12] A. Kadarohman, Hernani, F. Khoerunisa, R.M. Astuti, A potential study on clove oil, eugenol and eugenyl acetate as diesel fuel bio-additives and their performance on one cylinder engine, *Transport*, 25(2010) 66-67.

[13] G. Lepperhoff, G. Kroon, Impact of Particulate Traps on the Hydrocarbon Fraction of Diesel Particles, *SAE Transactions*, 94 (1985) 98-110.

[14] A.M. Ashraful, H.H. Masjuki, M.A. Kalam, I.M. Rizwanul Fattah, S. Imtenan, S.A. Shahir, H.M. Mobarak, Production and comparison of fuel properties, engine performance, and emission characteristics of biodiesel from various non-edible vegetable oils: A review, *Energy Conservation Management*, 80(2014) 202-228.

[15] Hebbal O D, Navindgi M.C, Ahmed I Elseesy, 2012. Comparison of cost efficiency of diesel blends, International Journal of Advanced Science and Research technology.229, 2265-2270.

[16] G.R. Rao, B.G. Mishra, Structural, redox and catalytic chemistry of ceria based materials, *Bulletin of the Catalysis Society of India*, 2(2013) 122-134.

[17] Ross Blanc, HaiterLenin.A, 2013, Performance characteristics of a diesel engine using nano additives as an alternate fuel, Iran.J. Energy Environ 4(2), 136-141.

[18] Devan, P.K., Mahalakshmi, N.V., 2009. Performance, emission and combustion characteristics of poon oil and its diesel blends in a DI diesel engine. Fuel 88, 861–867.

[19] Solaimuthu, C., Raghavan, V., Senthilkumar, D., Saravanan, C.G., 2015a. Experimental investigation of evaporation rate and emission studies of madhucaindica biodiesel and its blend with diesel. Int. Green Energy 12 (6), 635–640.

[20] H. Raheman, A.G. Phadatare, Agricultural and Food Engineering Department, Indian Institute of Technology, Kharagpur, India, "Diesel Engine Emissions and Performance from blends of methyle ester and Diesel" Biomass and Bio-energy.

Acknowledgment

The authors sincerely thank "The All India Council for Technical Education" (AICTE), New Delhi, India, for the financial assistance in carrying out this research work under Research Promotion Scheme (AICTE FILE NO: 8-29/RIFD/RPS/POLICY-1/2016-2017.Dated 02-08-2017).

About the License