Experimental Investigation on Emission Characteristics of Diesel-Neem Oil Biodiesel Blended with Nanoparticles in the Diesel-Powered Engine

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ABSTRACT

In the past two decades, the global energy demand has been troubled by uncertainty in two aspects. First, the price of conventional fossil fuels is very expensive, putting a further burden on the economies of importing countries. Second, the primary contributor to the increase in atmospheric carbon dioxide (CO_2) as a result of global warming is the burning of fossil fuels. So, we must introduce an alternate fuel that reduces the burden on the economies of importing countries and reduces the emission of harmful gases which cause global warming. Biodiesel is the best alternative to conventional diesel fuel which are both environmentally and economically friendly. For using biodiesel directly into the engine, there is no need for engine modification. Its main benefits include excellent lubricity, high biodegradability, and a lack of sulphur content. In the new era, not only biodiesel but also nanoparticles are widely employed by using their blends to decrease the emission of harmful gases and particles (like unburned hydrocarbons, nitrogen oxides, carbon dioxide, smoke, and many more) into the environment. The emission properties of three fuel series - pure diesel, biodiesel-diesel-TiO_2 nanoparticles, and biodiesel-diesel-CeO_2 nanoparticles - are examined in this experimental study. The titanium oxide (TiO_2) and cerium oxide (CeO_2) nanoparticles employed in this experimental inquiry were mixed with the fuel blends using an ultrasonicator at concentrations of 50 ppm, 100 ppm, and 150 ppm, respectively. By using biodiesel-diesel blends with nanoparticles as a fuel in the compression ignition engine, the diesel engine emits less pollutants.

Keywords: Biofuel, Nanoparticles, Biodiesel, fuel, emission characteristics

1 Introduction

Biodiesel is the best alternative to conventional diesel which are both environmentally and economically friendly. Biodiesel helps to reduce the emission of harmful gases. Biodiesel can be made from various oils like coconut oil, jatropha plant, soybean, waste oils, peanut trees, and many more. A.T. Hoang *et al.* [1] conducted an experiment with raw coconut oil with diesel fuel as an alternative to diesel engines. P. Mohamed Sameer *et al.* [2] observe that there are various benefits of biodiesel fuel like renewable, feasible, available, high combustion efficiency, and low emission of harmful gases. The advancement in injection timing of biodiesel into the engine helps to decrease the emission of hydrocarbon, smoke, carbon monoxide, and carbon dioxide but increases the emission of nitrogen oxide. And increasing the biodiesel's injection pressure into the engine increases the emission of unburned hydrocarbon, smoke, carbon monoxide, and nitrogen oxide but increases the emission of carbon dioxide. Increasing the injection pressure and advancing the injection timing can help to stimulate the emission characteristics of biodiesel into eco-friendly fuel. Angelo C. Pinto *et al.* [3] studied the process of making biodiesel and found that

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vegetable oils or animal fats are main sources for preparing the biodiesel. The process of producing biodiesel is transesterification. In transesterification, the triglyceride reacts with suitable alcohol having catalysts like sodium hydroxide produced biodiesel giving fatty acid esters which are biodiesel and glycerine. The mostly used catalysts at the industrial level are potassium and sodium hydroxide. Practically, the oil and corrected acid is transferred to the first reactor. In the second reactor, the catalysts like potassium and sodium hydroxide and alcohol like methanol and ethanol are homogenized and transferred to the first reactor. The reaction is taken place at 30 and 40 °C and is completed in 40 minutes. After completing the reaction, biodiesel is present in the upper layer and raw glycerine is present in the lower layer. The Biodiesel and raw glycerine are separated with the help of centrifugation or decantation. Natalina Damanik *et al.* [4] observed that biodiesel is gaining popularity because it is a cleaner alternative fuel and can be used directly and without modification in diesel engines. The majority of biodiesel blends modestly lower emissions of carbon monoxide and all other unburned hydrocarbons. When biodiesel is combined with nanoparticles, carbon dioxide, nitrogen oxide, and total unburned hydrocarbon emissions are also decreased, and diesel engine performance is enhanced. Prommes Kwanchareon *et al.* [5] conducted an experiment with a diesel-ethanol-biodiesel blend because the diesel-ethanol-biodiesel blend has similar properties to the diesel with standard limits. The flash point of the diesel-ethanol-biodiesel blend differs from that of conventional diesel fuel. The diesel-ethanol-biodiesel blend marginally reduces unburned hydrocarbon and carbon monoxide emissions at high load. The pour point and density of the diesel-ethanol-biodiesel blend are under the diesel standard limits. The phase separation is not a problem at above 20 °C temperature. Biodiesel produced from palm oil is an effective additive in a diesel-ethanol-biodiesel blend. Avinash Kumar Agarwal [6] studied that in addition to being utilised in pure form, biodiesel can be mixed with diesel in any amount to create a blend of diesel and biodiesel. Biodiesel can also be used directly like conventional diesel in CI engines and effectively requires little or no engine modification, as biodiesel has properties similar to petroleum diesel. It can be stored similarly to conventional diesel and thus does not need any additional infrastructure. Biodiesel's application in traditional diesel engines leads to a significant decline in emissions of unburned hydrocarbons, carbon monoxide, and particulate matter. A.S. Ramadhas *et al.* [7] observed that one of the most crucial characteristics for determining the ignition quality of any fuel for internal combustion engines is the cetane number. Determining the fuel cetane number by an experimental procedure is a difficult task and this difficulty is a problem in increasing biodiesel production in the industry. The cetane number of biodiesels made from base oils is significantly influenced by the fatty acid composition of the base oil. The cetane number of biodiesel ranges from 48 to 67 that depends on several factors including the processing technology of the oil and the climatic conditions at the time vegetable oil is obtained from various sources. P. Tamilselvan *et al.* [8] conducted an experiment with the biodiesel-diesel blend as an alternative fuel to conventional diesel and analysed the performance of engine. A number of alternative fuels are searched in the past decades like hydrogen fuel, biodiesel fuels, alcohol fuels, etc., and have been analysed extensively. In recent studies, it has been found that biodiesel is the best alternative for compression ignition engines due to its fewer effects on the environment and help to reduce the emission of harmful gases. There are many advantages of the diesel-biodiesel blend like less emission of harmful gases, less engine wear, reduction of engine oil utilization, and marginally high thermal efficiency compared to conventional diesel. Owolabi *et al.* [9] studied the benefits of the diesel-biodiesel blend and give proper validation for all of their benefits, including environmental benefits, and will thus play a crucial part in satisfying future fuel needs. The availability of important feedstock, notably oil derived from bio-sources, as well as the simplicity of the transesterification technology that ensures its transformation to biodiesel, are further benefits in relation to biodiesel's future requirements. Mc Cormick and Robert L. [10] conducted an experiment with a diesel-biodiesel blend to reduce the emission of unburned hydrocarbons, carbon monoxide, vapor-phase hydrocarbons from C1 to C12, ketones, and aldehydes up to 15%. The emission from 100% biodiesel has less effect on animals. Recent studies show that the most common diesel-biodiesel blend (20% biodiesel and 80% diesel) has no net effect on human beings. Oliveira and Da Silva [11] conducted an experimental investigation of tilapia visceral oil biodiesel blended with conventional diesel and discovered that the occurrence of tilapia visceral oil biodiesel blended with conventional fuel/diesel enhance the cetane number parameter. This is a most crucial part because a high cetane number improves combustion quality and reduces nitrogen oxide emissions. It also causes less noise and longer engine life. E.I. Bello and F. Otu [12] conducted an experiment with the diesel-biodiesel blend to improve the heating value and oxidation stability. However, because diesel has a lower flash point and a lower cetane number than pure biodiesel or 100% biodiesel, mixing reduces their values. Blending reduces kinematic viscosity, acid value, sulfated ash, carbon content, and oxidation. In terms of engine performance measures such as heating value and cetane number, B20 is the optimal blend. S. D. Jadhav and I. A. Shaikh [13] studied Nanoscale materials which is a substance that has at least one dimension is less than 100 nm. A nanometre is equal to 10^{-9} meters which is approximately one lakh times tinier than the human hair diameter. Nowadays, nanoparticles are used in various research fields due to their smaller sizes. M. Norhafana *et al.* [14] investigated strategies for minimizing the emission of harmful gases from CI engine. The primary strategy to reduce the emissions of toxic gases from the engine is by use of various devices such as particulate filters and catalytic converters. The second strategy to reduce the emission of harmful gases is by using fuel additives or blends of different fuels like diesel- biodiesel blends and many more. Nitrogen oxides and particulate matter are the main pollutants produced by diesel engines which pollute the environment. It is difficult to reduce the emission of nitrogen oxide and particulate matter at the same time. Rajesh K. *et al.* [15] studied that Especially in respect to the effects of the diesel-biodiesel blend, nano-additives in biodiesel successfully increase the overall performance of diesel engines without modifying the engines and also lower polluting emissions in the exhaust gases. Numerous studies contend that there is little heat emission and that adding nanoparticles to the diesel-biodiesel blend increases thermal efficiency. Thermal efficiency and heat release rate rise linearly as the quantity of nanoparticle additives increases in biodiesel. S. Hasan [16] studied the use of nanoparticles in a variety of industries, including medicine, solar energy, oxide fuel batteries for energy storage, optical devices, bactericidal agents, electronics, sensor technology, biological labelling, and the treatment of some cancers. They are also widely incorporated into a variety of everyday materials, including cosmetics and clothing. Nanoparticles have received a lot of interest in recent years because of their various advantages, including antibacterial properties, high oxidation resistance, and high thermal conductivity. Vishal Saxena *et al.* [17] observed advances in nanotechnology in recent years, The scientific community has concentrated on employing nanoparticles and blends of nanoparticles, diesel, and biodiesel to improve combustion behaviour, stability features, various engine performance parameters, and emission behaviour of conventional engines. Numerous improvements in the thermophysical and chemical properties of the modified fuel, including a high surface area to volume ratio, a highly reactive ignition medium, improved heat and mass transfer properties because of high thermal conductivity, and an increase in flash point and pour point are observed. All these are depending on the kind, size, and concentration of the nanoparticles employed in the base fuel. Amar Kumar Das *et al.* [18] employed nanographene with pyrolysis oil as a fuel because The properties of pyrolysis oil made from plastic waste have been compared to diesel and found to be similar enough to be used as an alternative fuel. The brake thermal efficiency of 20% plastic oil blended with diesel fuel dispersed in 100 ppm graphene increased by 1.16% at a compression ratio of 17:1 compared to conventional diesel. The emission of hydrocarbons, nitrogen oxide, and carbon monoxide are also significantly reduced by adding 100 ppm nanographene to waste plastic oil compared to the other fuel blends. According to research by Siti Nurul Akmal Yusof *et al.* [19], a nanofluid is a colloidal dispersion of nanoparticles dispersed in a liquid media. In a number of technical applications, it improves heat transfer characteristics and encourages great energy efficiency. Nanoparticles have a key role in developing enhanced combustion quality. By incorporating nanoparticles into diesel/biodiesel, fuel characteristics like kinematic viscosity, caloric value, flash point, density, and cetane number can be enhanced, leading to complete combustion. Aluminium is the best metal candidate, whereas carbon nanotubes are employed for non-metal nanoparticles. This is due to the availability of sufficient oxygen, and the positive aspects of nanoparticles on the fuel characteristics of diesel/biodiesel combined may greatly improve combustion efficiency, resulting in reduced brake specific fuel consumption and hazardous emissions. Mahendra Varman R. *et al.* [20] conducted an experiment using iron oxide nanoparticles as additives in diesel fuel and observed that iron oxide nanoparticle additives are effective in lowering emissions in the diesel engine. The emission of hazardous gases could be significantly reduced by using iron oxide nanoparticles as additives in diesel fuel. Emissions of hydrocarbons and nitrogen oxides have been reduced by up to 30% and 22%, respectively. When compared to diesel fuel, carbon monoxide emissions increased slightly. S. Gavhane *et al.* [21] observed that adding zinc oxide nanoparticles in soybean biodiesel improves the properties of fuel like cetane number, and calorific value. Additionally, it enhances the engine's performance characteristics and reduces the brake specific fuel consumption by 20.37% compared to soybean biodiesel only. Carbon dioxide, smoke, hydrocarbon, and carbon monoxide emissions are reduced by 21.66 percent, 22.54 percent, 30.83 percent, and 41.08 percent; respectively, however, nitrogen oxide emissions are slightly increased due to the additional oxygen. Zirconium oxide nanoparticle additive in diesel-juliflora oil biodiesel was the subject of experiments by R. Sabarish *et al.* [22], who found that it reduced emissions of nitrogen oxides, carbon dioxide, carbon monoxide, hydrocarbons, and smoke when compared to clean diesel and biodiesel. It also improves the engine performance and combustion characteristics. Ayse Busra Sengul and Eylem Asmatulu [23] studied that Nanotechnology has recently been used in a variety of areas, including consumer goods, medicine, and the environment. Nanoparticles have distinctive capabilities that vary greatly depending on their size, shape, composition, aggregation, and homogeneity states. Carbon-based nanoparticles, metal-based nanoparticles, organic-based nanoparticles, and composite-based nanoparticles are examples of nanomaterials. Jiangjun Wei *et al.* [24] conducted an experiment on aluminium oxide nanoparticles blended with diesel-methanol which is possible due to the development of nanotechnology. The aluminium oxide nanoparticles added to the blend of the diesel-methanol help to reduce the emission of hydrocarbons, carbon monoxide, and smoke, but slightly increase the emission of nitrogen oxide. And the performance and the combustion of fuel in the engine are slightly enhanced. It is shown that the presence of nanoparticles in diesel-methanol helps to improve the overall performance of the engine and helps to make the environment clean. D. Ramesh *et al.* [25] conducted experiment with jatropha biodiesel blended with diesel fuel because the properties of diesel fuel are similar to jatropha biodiesel. Jatropha biodiesel consumes 14 percent extra fuel as compared to conventional diesel. The diesel-jatropha biodiesel blend gives slightly high Brake thermal efficiency compared to conventional diesel. The percentage reduction in emission of carbon monoxide with biodiesel at 2 kW, 2.5 kW, and 3.5 kW are 16, 14, and 14 respectively. But the percentage increase in emission of nitrogen oxide with biodiesel at 2 kW, 2.5 kW, and 3.5 kW are 15, 18, and 19 respectively compared to conventional diesel.

Ali Rashid [26] observed that diesel exhaust contains a complicated mixture of around 450 different elements, including vapours and tiny particles. The state of California considers more than 40 compounds in diesel exhaust to be harmful air pollutants. Diesel exhaust can cause cancer, as well as irritation of the eyes, nose, throat, and lungs, as well as coughing, migraines, and nausea. Diesel exhaust also causes lung inflammation, which can aggravate chronic respiratory problems and increase the frequency or severity of asthma attacks and other medical difficulties. Lloyd and Cackette [27] studied that diesel engines have a harmful influence on the natural environment in all aspects, including land, water, and air. In occupational and general population epidemiologic investigations, diesel PM has been linked to lung cancer and short-term respiratory disorders such as asthma. Tiny particles, both directly released by diesel engines and produced by gaseous contaminants, can lead to early deaths and serious respiratory problems. Tumors and damaged cells have been seen in animals exposed to high amounts of diesel particulate matter, despite the fact that these levels are often much higher than in natural habitats. A. Sydbom *et al.* [28] studied the effect of exhaust emission from a diesel engine on human health because exhaust emission is a combination of gases and particles exhausted after the combustion of diesel fuel. This mixture of gases and particles is the cause of air pollution. This air pollution is the cause of various diseases like exacerbation of asthma, stroke, heart disease, and respiratory infections. The acute effects of exhaust gases from diesel fuel are headache, irritation in the eyes and nose, fatigue, lung's function interrupted, and breathing problems. The exhaust gases and particles from diesel fuels also affect the health of animals.

The objective of this experimental investigation is to give detailed information on emission characteristics of biodiesel-diesel blended with nanoparticles in the compression ignition engine. The nanoparticles and biodiesel used in this experimental investigation is Titanium oxide (TiO_2), Cerium oxide (CeO_2), and Neem oil biodiesel. The three test fuels are used: pure diesel, biodiesel-diesel- TiO_2 nanoparticle blend, and biodiesel-diesel-CeO_2 nanoparticle blend. Using an ultrasonicator, titanium oxide (TiO_2) and cerium oxide (CeO_2) nanoparticles in concentrations of 50 ppm, 100 ppm, and 150 ppm are introduced to the fuel blends.

2 Experimental Setup and Procedure

The whole research is conducted by using three test fuels: pure diesel, diesel-biodiesel-cerium oxide nanoparticle blend, and diesel-biodiesel-titanium oxide nanoparticle blend. The biodiesel used in this experimental analysis is neem oil biodiesel. The properties of neem oil diesel fuel are shown in Table 1. The conclusion of the experiments showed that biodiesel fuels release less harmful pollutants than conventional diesel. Moreover, the supplement of nanoparticles to biodiesel fuel decreases the production of harmful gases when compared to pure biodiesel fuel. The importance of the decreased ignition delay effect associated with nanoparticles blended biodiesel fuels has also been studied. Additionally, the significance of the reduced ignition delay effect linked to biodiesel blends with nanoparticles has been researched.

Table 1: *Properties of Biodiesel*

Specification	value
Density	0.82-0.84 g/cm^3
Calorific Value	10500 Kcal/Kg
Cetane Number	47-53
Flash Point	147 °C
Kinematic Viscosity @40 °C	2 mm^2/s

The emission properties of the engine are investigated in this experimental study by utilizing a single-cylinder, four-stroke, variable compression ratio (VCR) engine test system. Table 2 provides more details on the variable compression ratio (VCR) diesel engine specifications and testing setup. The VCR engine/ testing setup and its line diagram is shown in figure 1 and figure 2, respectively. Diesel was used to start the diesel engine initially, and then the test fuels were supplied to run the engine. Diesel and test fuel emissions are tested at compression ratios of 14, 16, and 18 and under a load of 12 kg. The emission characteristics of diesel and test fuel is measured are carbon monoxide (CO), unburnt hydrocarbon (HC), oxygen (O_2), carbon dioxide (CO_2), and nitrogen oxide (NO_x) emissions for both diesel and the prepared test fuels with the help of Aerosmart exhaust gas analyzer model no. AEG051.

Table 2. *Specification of the engine*

Specification	Unit	Specification	Unit
Maker	Kirloskar	Rated power	5.2 KW
No. of cylinder	1	Rated speed	@1500 RPM
No. of stroke	4	Cylinder diameter	87.5 mm
Stroke length	110 mm	Compression ratio	12 to 18:1
Connected rod length	234 mm	Orifice diameter	20 mm
Dynamometer arm length	185 mm	Cooling type	Water-cooled
Injection Pressure	200 bars		

The scope of this study focuses on two nanoparticles: titanium oxide (TiO_2) and cerium oxide (CeO_2). The chemical, physical, and thermal characteristics are shown in Table 3.

Titanium is one of the most unique metals. Titanium dioxide, commonly known as Titania, is the visibly occurring mixture produced when titanium combines with the oxygen in the air. In the form of liquid, titanium oxide (TiO_2) is accessible. Titanium oxide is magnetic, although cerium oxide is far less toxic than other nanoparticles.

An experimental study was conducted to examine the performance and emission characteristics of a compression ignition engine using biodiesel made from neem oil, diesel, and additives. For this research investigation, we use B20 (comprising 20% biodiesel and 80% diesel in volume percentage), T50, T100, T150 (50 PPM Titanium oxide, 100 PPM Titanium oxide, 150 PPM Titanium oxide respectively), C50, C100, C150 (50 PPM Cerium oxide, 100 PPM Cerium oxide, 150 PPM Cerium oxide respectively). In terms of carbon monoxide, oxygen, hydrocarbons, carbon dioxide, and nitrogen oxide, the emission characteristics of diesel engine and test fuel were measured at compression ratios of 14, 16, and 18 and at a load of 12 kg, and the results are presented below.

Figure 1: *VCR engine and testing setup*

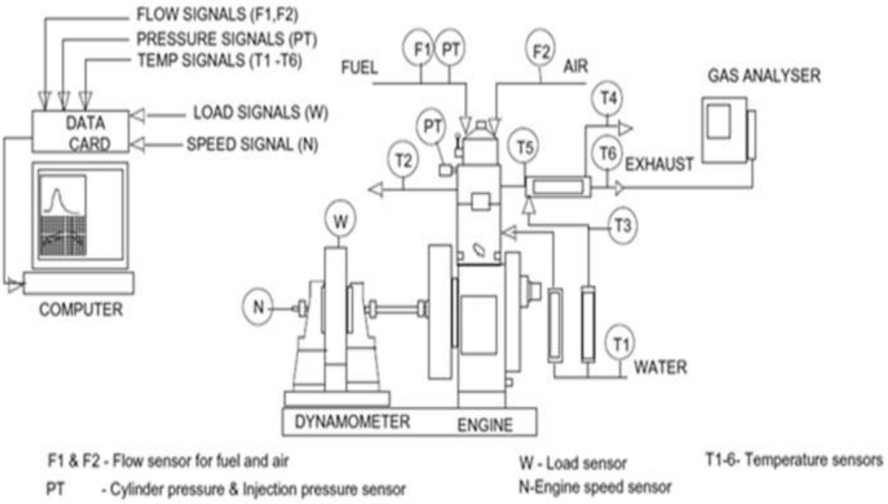

Figure 2: *Line diagram of engine and testing setup*

Table 3: *Chemical, Physical, and Thermal characteristics of Nanoparticles*

Properties	Nanoparticles	
	TiO_2	CeO_2
Titanium, Cerium %	59.93%	56.53%
Oxygen %	40.55%	45.65%
IUPAC Name	Dioxotitanium	dioxocerium
Molecular mass	79.9378 g/mol	171.895 g/mol
Specific surface area	36 - 65 m^2/g	9.5 m^2/g
Size range	20 - 40 nm	60 - 200 nm
Density	4.23 g/ cm^3	7.13 g/-cm^3
Molar mass	79.9378 g/mol	172.115 g/mol
Melting Point	1843 °C	2340 °C
Boiling Point	2972 °C	3500 °C
Specific heat	692 J/kg K	390 J/kg K
Thermal conductivity	8.4 W/m-K	6.6 W/m-K
CAS No	13463-67-7	1306-38-3
Appearance	White powder	Yellow powder

3 Result and Discussion

The fuel mixture/blend which is used in this experimental analysis are B20 T (50, 100, 150) i.e., biodiesel-diesel- TiO_2 nanoparticle blend and B20 C (50, 100, 150) i.e., biodiesel-diesel-CeO_2 nanoparticle blend). The nanoparticles Titanium oxide (TiO_2) and Cerium oxide (CeO_2) of each 50 ppm, 100 ppm, and 150 ppm is added to the fuel blends by means of an ultrasonicator. Diesel engine emission characteristics were analysed at 14, 16, 18 compression ratios with 12 Kg load capacity. In which main focus was on carbon monoxide emission, hydrocarbon emission, carbon dioxide emission, nitrogen oxide emission and oxygen emission which are as given below-

3.1 Analysis of Carbon monoxide (CO) during emission

Lack of oxygen, incorrect fuel mixing, or incomplete fuel combustion can contribute to the formation of carbon monoxide. Carbon monoxide is an odourless and colourless gas. The minimum % vol. of carbon monoxide is observed by the Biodiesel-diesel-CeO_2 nanoparticle sample is 0.01% vol. It is noticed that B20CR18C100 reduces the amount of carbon monoxide in the exhaust gases to a minimum. The % vol. of carbon monoxide of conventional diesel at combustion ratio (CR) 18 is 0.02% vol. Maximum % vol. of carbon monoxide for CeO_2 is found at 14 CR & at 150 PPM. For all compression ratios and PPM concentration levels, TiO_2 additives created carbon monoxide on the upper side in compression to CeO_2. Figure 3 shows the comparison between % vol. of carbon monoxide of CeO_2 sample, TiO_2 sample, and pure diesel during emission.

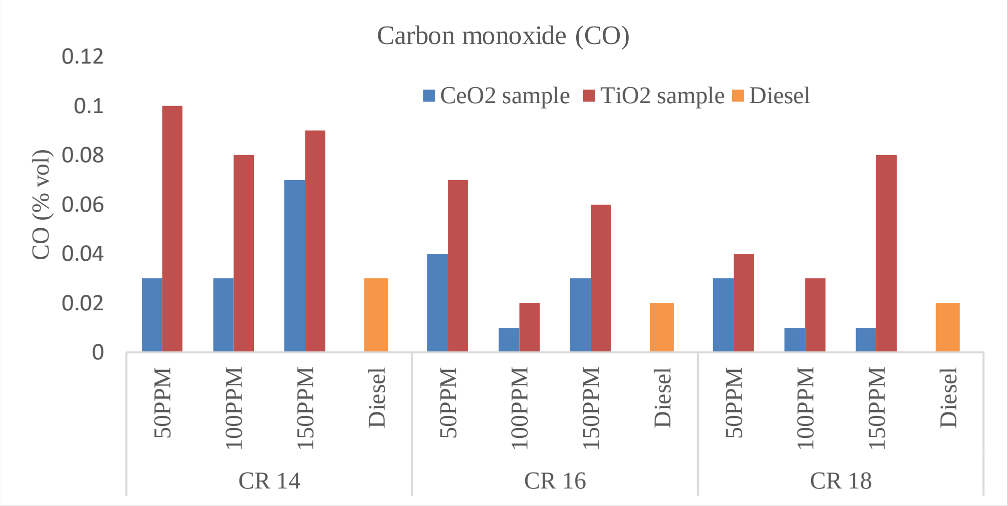

Figure 3: *% Vol. of carbon monoxide of CeO_2 sample, TiO_2 sample, and Diesel during emission*

3.2 Analysis of Oxygen (O_2) during emission

Figure 4 shows the comparison between % vol of oxygen emitted by engine for CeO_2 sample, TiO_2 sample, and Diesel. The maximum % vol of oxygen is emitted by using Biodiesel-diesel-CeO_2 nanoparticle sample, is 20.5% vol. and it is approximately same for B20CR18C100 and B20CR18C150 test fuel. The % vol of oxygen of conventional diesel at combustion ratio 18 is 19.27% vol. For all compression ratios and PPM concentration levels, TeO_2 additives-based fuel emitted less oxygen in compression to CeO_2.

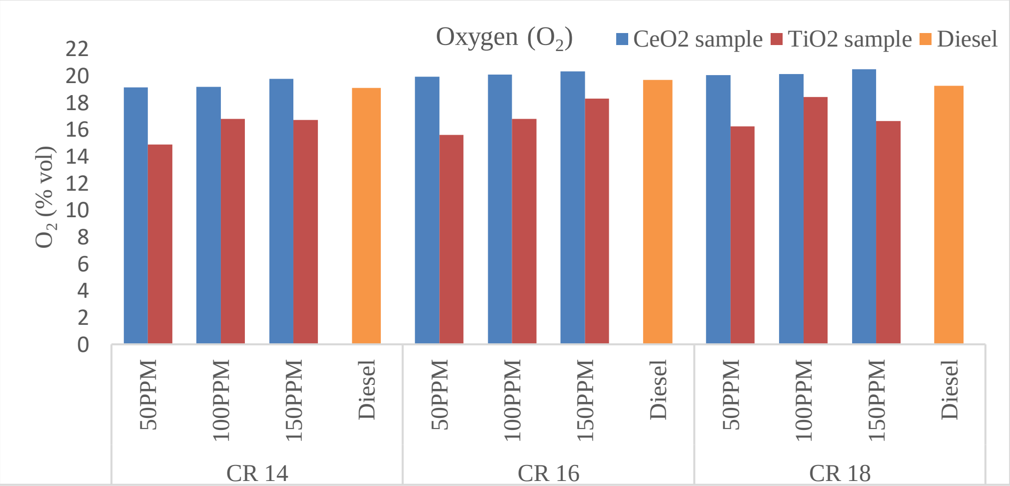

Figure 4: *% Vol of oxygen of CeO_2 sample, TiO_2 sample, and Diesel during emission*

3.3 Analysis of Hydrocarbons (HC) during emission

Fuel that burns insufficiently or ignites incorrectly might result in the formation of hydrocarbons. It varies if the mixture of fuel is excessively lean or rich.

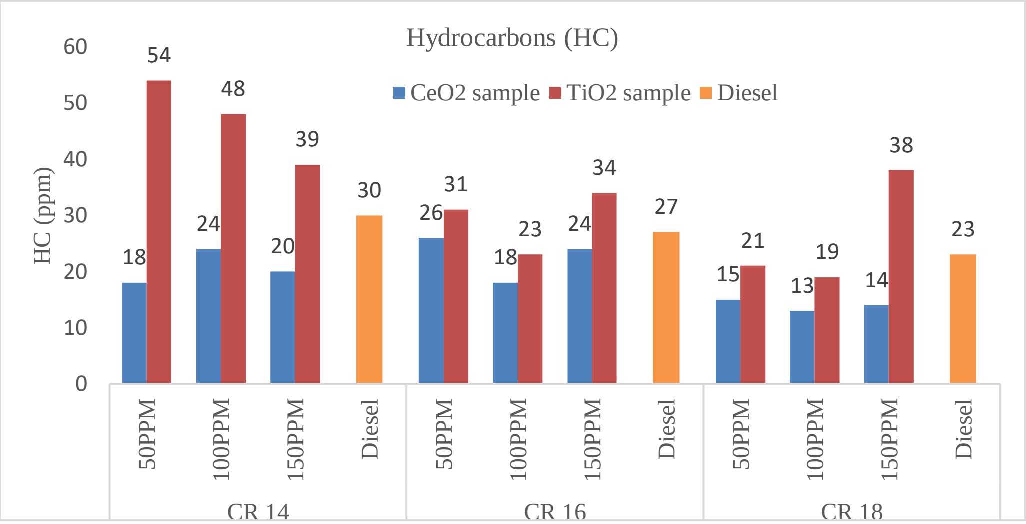

Figure 5: *Hydrocarbons concentration of CeO_2 sample, TiO_2 sample, and Diesel during emission*

The minimum hydrocarbons concentration (13 ppm) emitted by the engine at B20CR18C100 Biodiesel-diesel-CeO_2 nanoparticle sample. The hydrocarbons concentration of diesel at combustion ratio 18 is 23 ppm while for same compression ratio and same PPM, TeO_2 produce high number of hydrocarbons (i.e., 38 ppm). Figure 5. Show the comparison between hydrocarbons concentration of CeO_2 sample, TiO_2 sample, and Diesel.

3.4 Analysis of Carbon dioxide (CO_2) during emission

Carbon and hydrogen atoms are present in diesel fuel. During combustion, the carbon from diesel fuel is combined or mixed with the oxygen from the air to produce carbon dioxide. The minimum % vol of carbon dioxide is achieved by the Biodiesel-diesel--CeO_2 nanoparticle sample is 1.9% vol. The minimum % vol of carbon dioxide from the exhaust gases is achieved by B20CR18C150 which is slightly less than B20CR18C100. The % vol of carbon dioxide of diesel at combustion ratio 18 is 2.9% vol. Figure 6. Show the comparison between % vol of carbon dioxide of CeO_2 sample, TiO_2 sample, and Diesel.

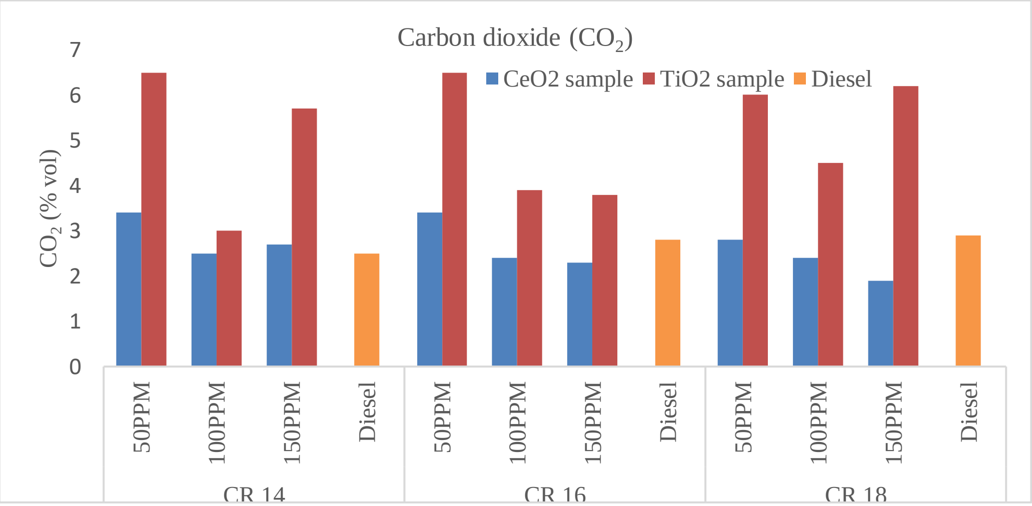

Figure 6: *% Vol of carbon dioxide of CeO_2 sample, TiO_2 sample, and Diesel during emission*

3.5 Analysis of Nitrogen oxide (NO_x) during emission

The temperature inside the engine cylinder is high due to fuel combustion. Nitrogen monoxide is produced when nitrogen interacts or is mixed with oxygen from the air at extremely high temperatures. The minimum nitrogen oxide concentration achieved by the Biodiesel-diesel-CeO_2 nanoparticle sample is 305 ppm. The minimum nitrogen oxide concentration from the exhaust gases is achieved by B20CR18C100. The nitrogen oxide concentration by the diesel at combustion ratio 18 is 502 ppm. Figure 7 Shows the comparison between nitrogen oxide concentration of CeO_2 sample, TiO_2 sample, and Diesel.

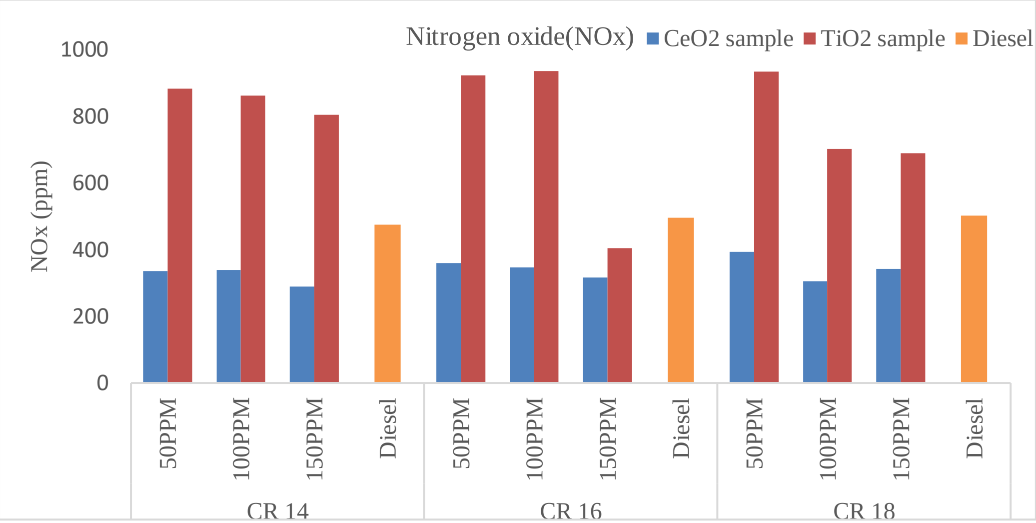

Figure 7: *Nitrogen oxide concentration of CeO_2 sample, TiO_2 sample, and Diesel during emission*

4 Conclusions

- The minimum % vol of carbon monoxide from the exhaust gases is achieved by B20CR18C100 test fuel which is 0.01% vol. The percentage reduction of carbon monoxide by using B20CR18C100 test fuel is 50% in compression to diesel fuel.
- The maximum % vol of oxygen from the exhaust gases is achieved by the B20CR18C150 & B20CR18C100 test fuel which is 2.5% vol. The percentage increment of oxygen by using B20CR18C100/150 test fuel is 6.38% in compression to diesel fuel.
- The minimum hydrocarbons concentration from the exhaust gases is achieved by B20CR18C100 test fuel is 13 ppm. The percentage reduction of hydrocarbons concentration by using B20CR18C100 test fuel is 43.47% in compression to diesel fuel.
- The minimum % vol of carbon dioxide from the exhaust gases is achieved by B20CR18C150 test fuel is 1.9% vol. The percentage reduction of carbon dioxide by using B20CR18C150 test fuel is 34.48% in compression to diesel fuel.
- The minimum nitrogen oxide concentration from the exhaust gases is achieved by B20CR18C100 test fuel is 305 ppm. The percentage reduction of nitrogen oxide concentration by using B20CR18C100 test fuel is 39.24% in compression to diesel fuel.

5 Publisher's Note

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How to Cite

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