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Original Research Article

Influence of $NiFe_2O_4$ and $Zn_{0.5}Ni_{0.5}Fe_2O_4$ nanoparticles on exhaust emissions of 4 stroke-6 cylinders turbocharged diesel engine

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ABSTRACT

Diesel vehicles have a huge role in the transportation of goods and people however they cause air pollutions. For this reason, researchers try to find alternative fuel additives to decrease the exhaust emissions. This experimental work focus on the impacts of oxygen content nanoparticle additives on exhaust emissions of 4 Stroke-6 cylinders turbocharged diesel engine fuelled with diesel fuel. Nickel iron oxide and nickel zinc iron oxide nanoparticles with the dosage of 15, 20 and 25 ppm were used as additives in the experimental tests. According to the results, the optimum dosage level of nanoparticles was found. As finally, the results revealed that the exhaust emission values were decreased with the nanoparticle addition to diesel fuel.

Keywords: Nanoparticle; nickel iron oxide; nickel zinc iron oxide; exhaust emissions; diesel engine

1. Introduction

Petroleum resources have a huge role in energy demanding. However, the depletion of petroleum fuels is increasing rapidly [1]. In the world diesel engines are mostly used in motor vehicles, automobiles, manufacturing power generation, farming [2-3]. Diesel vehicles induced to the many air pollutants like carbon monoxide, carbon dioxide, hydrocarbons, particulate matter, nitrogen oxides and soot emissions [4-5]. Due to the economic and environmental concerns have led to the find alternative fuel for diesel engine [6]. Various fuel additives are used in order to beat adverse effects of diesel fuel [7-8]. According to many research studies that adding nanoparticle to diesel and biodiesel fuels improve combustion efficiency and reduction exhaust emissions [9-11]. Many researchers used metal-based additives which posses' desirable properties such as high thermal conductivity, surface-volume ratio, and better ignition characteristics [12]. There are many nano additives such as zinc oxide, manganese, carbon nanotube, cerium oxide, iron oxide, alumina, copper oxide, titanium oxide, magnesium oxide [3,7,13].

Rastogi et. al [12] carried out experimentally study to find the effects of CuO nanoparticles on performance of diesel engine, emission and combustion characteristics which runs on jojoba biodiesel blend (JB20) as a fuel. They added 25, 50 and 75 ppm CuO to JB20. They observed that BTE for the JB20CN50 fuel was higher than that of other Jojoba biodiesel fuel samples and engine emission hydrocarbons, CO and smoke emissions were also found lesser when the CuO nanoparticles added to JB20.

Srinidhi et. al [13] investigated the impacts of NiO nanoparticle doped azadirachta indica biodiesel-diesel fuel (NBE25) blend on CI engine performance at different fuel injection timing. Nickel oxide nanoparticle concentration was 25, 50, 75 and 100 ppm in NBE25 base fuel. According to the outcomes there is an important reduction on HC and CO emissions for the nickel oxide mixed biodiesel compared with a biodiesel blend (NBE25).

Özgür et. al. [14] had examined the engine performance and emission parameters of diesel engine by using SiO_2 and MgO nanoparticles mixed with rapeseed biodiesel. Nano particles were added to biodiesel with mass fractions of 25 and 50 ppm. According to the results, they observed a reduction in NO_x and CO emission values and engine performance increased with the addition of SiO_2 and MgO nanoparticle additives.

Mehregan and Moghiman [15] explored the effects of nano additives on performance and emission characteristics of diesel engine equipped with urea-SCR system fuelled with blended biodiesel fuel. They used manganese oxide and cobalt oxide as nanoparticle additives at the dosage of 25 and 50 ppm. They found that the brake specific fuel consumption and the brake thermal efficiency increased with the addition of nanoparticles and they observed reduction in the NO_x and CO emissions compared to those of base fuel.

Kumar et. al. [16] studied the emission behaviour of four stroke, single cylinder, diesel engine fuelled diesel fuel adding with TiO_2 nanoparticle. They added 50 and 100 ppm TiO_2 nanoparticle to diesel fuel. They observed that adding 50 and 100 ppm of TiO_2 nanoparticles to diesel, significant reduction in CO, HC, NO_x, and smoke emissions.

The goal of this experimental work is to examine the influence of Nickel Iron Oxide and Nickel Zinc Iron oxide in diesel fuel as an additive to determine the exhaust emissions in 4 Stroke-6 cylinder turbocharged diesel engine.

2. Experimental Set up

In this experimental study, diesel was used as fuel. Nickel iron oxide and nickel zinc iron oxide nanoparticle additives which are commercially available with size 30 nanometers were used to prepare fuel blends. The amount of nanoparticles that are required for all level of doses were measured using electronic precision scales with sensitivity of 0,0001 g. The chosen dosage levels of nanoparticles were 15, 20 and 25 ppm. Nickel iron oxide and nickel zinc iron oxide nanoparticles added to diesel fuel with Sonic Vibra-Cell VC 750 model ultrasonic processer during half an hour to obtain a homogeneous fuel mixture. These test fuels were used in order to prevent any precipitation without delay. The properties of nanoparticles are given Table 1.

Table 1. The Properties of nanoparticles

Nanoparticle	Symbol	Particle Size (nm)	Purity (%)
Nickel Iron Oxide	$NiFe_2O_4$	30	99.9
Nickel Zinc Iron Oxide	$Zn_{0.5}Ni_{0.5}Fe_2O_4$	30	99.5

The measured fuel properties are density, kinematic viscosity, cetane number and pour point. Table 2 represents the specifications of fuel properties measurement devices.

Table 2. Specifications of fuel devices

Property	Device	Accuracy
Density (kg/m^3)	Kyoto Electronics DA-130	±0.001 g/cm^3
Kinematic viscosity (cSt)	Tanaka AKV-202	±0.01cSt
Cetane number	Zeltex ZX 440	±0.5
Pour Point (°C)	Tanaka MPC 102L	±1 °C

In this work, a 6-cylinder, 4 stroke, turbocharged and charge air cooled intercooled diesel engine which was run on a hydraulic dynamometer is used. The technical properties of engine test show on Table 3. Lay out of the system was demonstrated in Figure 1. The experimental tests were conducted at full load condition between 1400 and 2200 rpm, with an interval of 200 rpm. AVL SESAM Fourier Transform Infrared Spectroscopy (FTIR) multi-component exhaust analyser were used to measure exhaust emission concentrations. The accuracy of the measurements is 0.01 for all types of exhaust emissions.

In the after treatment process, selective catalytic reduction, which involves the spraying of urea in the tail pipe, was incorporated to mitigate NO_x. The engine is equipped with SCR aftertreatment system. The specifications of catalyst used in SCR system are shown in Table 4.

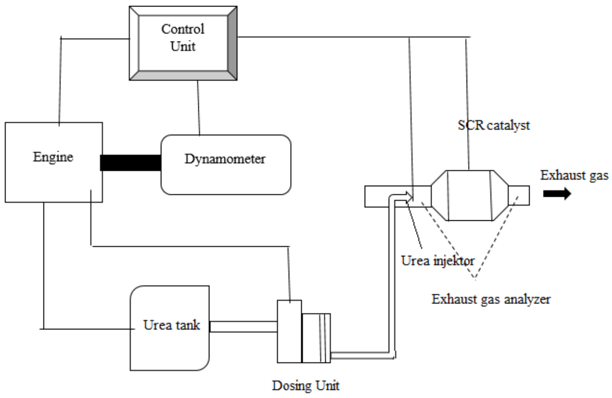

Figure 1. Lay out of the system

Table 3. Characteristics of test engine

Specifications	Descriptions
Manufacturer/series type	Cummins ISBE4+250B
Engine type	Electronic control system, 4 stroke, 6 cylinder, Turbocharger & aftercooled
Bore	107 mm
Stroke	124 mm
Compression ratio	17.3
Displacement	6700 cc
Power	184 kW@2500 rpm

Table 4. Specifications of the catalyst in Aftertreatment system

Specifications	Descriptions
Diameter (m)	0.2667
Length (m)	0.3048
Cell Geometry	Honeycomb type square celled catalyst
Total Volume (L)	17
Cell Density/in^2	400
Cell Width (mm)	1.2
Open Frontal Area (m)	1.86
Wall Thickness (mm)	0.105
Thermal conductivity (W/m.K)	0.4

3. Results and Discussion

3.1. Fuel properties

Density, viscosity, cetane number and pour point values were measured according to the standards. The fuel properties of diesel fuel and test fuels are demonstrated in Table 5. According to the table, density and pour point of diesel fuel does not show important variation, with the addition of nanoparticles to diesel fuel. The viscosity of diesel fuel was slightly increased with the addition of nanoparticles to diesel fuel. Cetane number of the test fuels decreased with the addition of nanoparticles. Cetane number is the the ignition quality of a fuel. Decrease in the cetane number means decrease in the ignition quality of the fuel which will lead to poor combustion of the fuel in the combustion chamber [17].

Table 5. Fuel properties of diesel fuel and test fuels

Property	Density	Viscosity	Cetane number	Pour Point
Units	kg/m^3	cSt	-	°C
Diesel	840	3.5	59	-13
15 ppm Ni Fe_2O_4	840	3.6	50	-13
20 ppm Ni Fe_2O_4	840	3.6	51	-13
25 ppm Ni Fe_2O_4	841	3.7	53	-13
15 ppm $Zn_{0.5}Ni_{0.5}Fe_2O_4$	841	3.7	49	-13
20 ppm $Zn_{0.5}Ni_{0.5}Fe_2O_4$	841	3.8	51	-13
25 ppm $Zn_{0.5}Ni_{0.5}Fe_2O_4$	842	3.9	52	-13

3.2. NO_x Emissions

Figure 2 is given NO_x emissions of test fuels versus engine speed. The chosen addition dosage of $NiFe_2O_4$ nanoparticle is 15, 20 and 25 ppm. As the nanoparticle dosage increased, a reduction in the emission values was observed. The percentage alteration of NO_x emissions of test fuels compared to neat diesel fuel is given in Figure 3. According to the results, the average reduction is 5.5%, 7.4% and 8.5% for the addition dosage of 15, 20 and 25 ppm respectively.

The variations of NO_x emission values of $Zn_{0.5}Ni_{0.5}Fe_2O_4$-diesel fuel blends with different engine speed is demonstrated in Figure 4. According to the results the maximum reduction in NO_x emissions was measured with modified fuel with the $Zn_{0.5}Ni_{0.5}Fe_2O_4$ addition dosage of 25 ppm. The maximum nitrogen oxides emission decrease was acquired at 2200 rpm engine speeds for the all test fuels. The average reduction in NO_x emission is 2.3 %, 3.2 % and 4.7 % with respect to neat diesel at the addition

Table 6. The changes in NO_x emissions with the addition of nanoparticles to diesel engine

		$NiFe_2O_4$-diesel fuel blends		
rpm	Diesel	15 ppm $NiFe_2O_4$	20 ppm $NiFe_2O_4$	25 ppm $NiFe_2O_4$
1400	1128.0000	1041.0000	1035.0000	1023.0000
1600	998.0000	978.0000	970.0000	962.0000
1800	939.0000	918.0000	872.0000	863.0000
2000	865.0000	830.0000	805.0000	800.0000
2200	828.0000	732.0000	728.0000	712.0000
		$Zn_{0.5}Ni_{0.5}Fe_2O_4$-diesel fuel blends		
rpm	Diesel	15ppm $Zn_{0.5}Ni_{0.5}Fe_2O_4$	20ppm $Zn_{0.5}Ni_{0.5}Fe_2O_4$	25ppm $Zn_{0.5}Ni_{0.5}Fe_2O_4$
1400	1128.0000	1107	1102	1098
1600	998.0000	971	967	960
1800	939.0000	937	932	910
2000	865.0000	861	852	840
2200	828.0000	775	758	735

dosage of 15, 20 and 25 ppm respectively. The reason of the reductions in NOx emission of diesel fuels with the addition nanoparticles is complete combustion of oxygenated fuel blends with the help of catalyst effect of nanoparticle additions which promotes heat transfer in the combustion chamber due to their metallic-base structures [18].

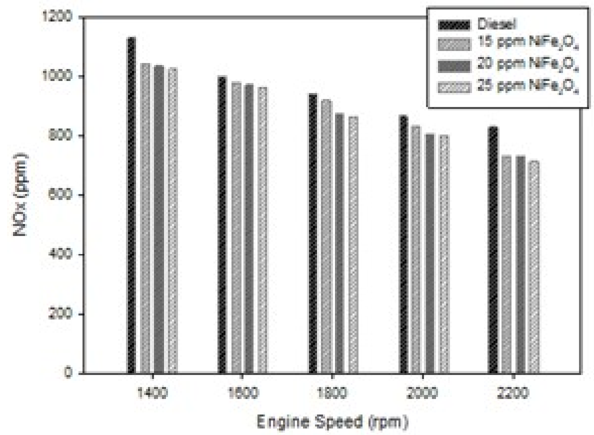

Figure 2. Experimental NO_x emission data to $NiFe_2O_4$-diesel

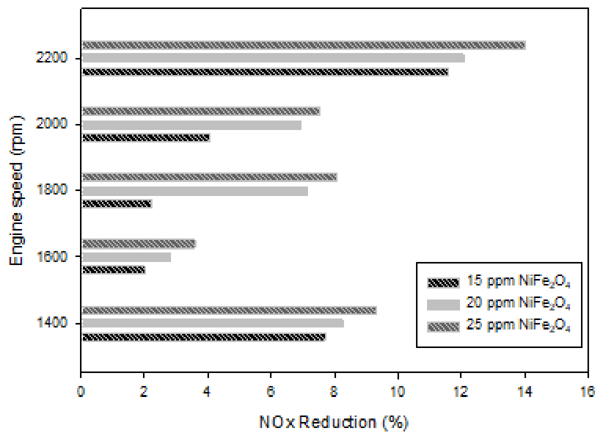

Figure 3. Percentage alteration of NO_x emissions of test fuels compared to diesel fuel

Table 6 gives the changes in NO_x emissions with the addition of nanoparticle to diesel fuel at different engine speeds.

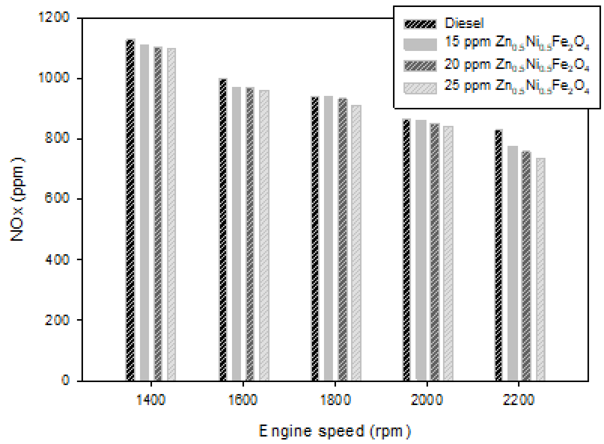

Figure 4. Impacts of $Zn_{0.5}Ni_{0.5}Fe_2O_4$-diesel blends on NOx Emission

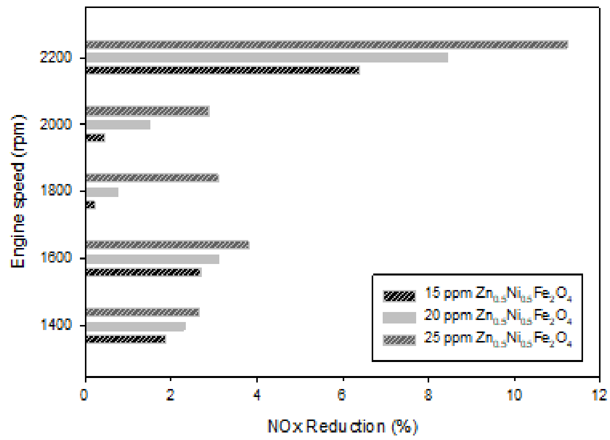

Figure 5. Percentage alteration of NO_x emissions of test fuels compared to diesel fuel

3.3. CO Emissions

Figure 6 presents the carbon monoxide (CO) emissions of modified fuel blends. It is observed that CO emissions are decreased with the addition of $NiFe_2O_4$ nanoparticle to diesel fuel. Figure 7 shows percentage alteration of CO emissions of test fuels compared to neat diesel fuel. The average reduction in CO emission with

Table 7. The changes in CO emissions with the addition of nanoparticles to diesel engine

		$NiFe_2O_4$-diesel fuel blends		
rpm	Diesel	15 ppm $NiFe_2O_4$	20 ppm $NiFe_2O_4$	25 ppm $NiFe_2O_4$
1400	88	85.0000	82.0000	79.0000
1600	77	74.0000	71.3000	70.0000
1800	125	118.0000	110.0000	105.8000
2000	402	395.0000	382.0000	378.2000
2200	439	418.0000	411.0000	407.8000
		$Zn_{0.5}Ni_{0.5}Fe_2O_4$-diesel fuel blends		
rpm	Diesel	15ppm $Zn_{0.5}Ni_{0.5}Fe_2O_4$	20ppm $Zn_{0.5}Ni_{0.5}Fe_2O_4$	25ppm $Zn_{0.5}Ni_{0.5}Fe_2O_4$
1400	88	86	83	78
1600	77	76	75	73
1800	125	111	108	105
2000	402	399	395	386
2200	439	435	431	428

respect to neat diesel result 3.9%, 7.5% and 9.5% with respect to diesel at the $NiFe_2O_4$ nanoparticle addition dosage of 15, 20 and 25 ppm respectively.

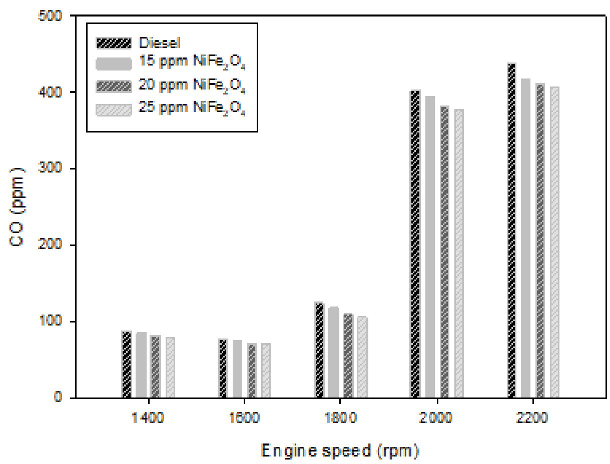

Figure 6. CO emissions of $NiFe_2O_4$-diesel blends at different engine speeds

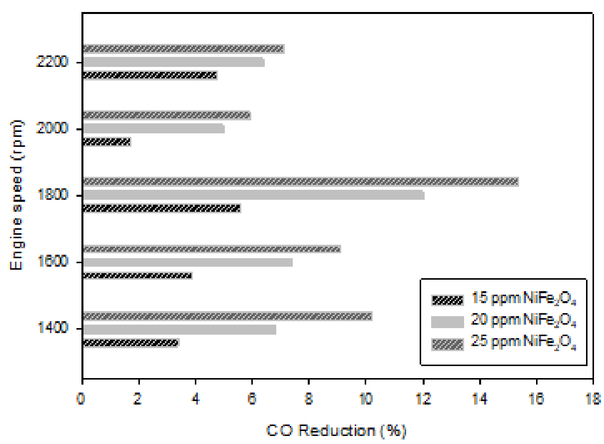

Figure 7. Percentage alteration of CO emissions of test fuels compared to diesel fuel

Figure 8 shows the carbon monoxide (CO) emissions of $Zn_{0.5}Ni_{0.5}Fe_2O_4$-diesel fuel blends at different engine speeds. According to the results nanoparticle addition dosage of 15, 20 and 25 ppm decreased the CO emissions with

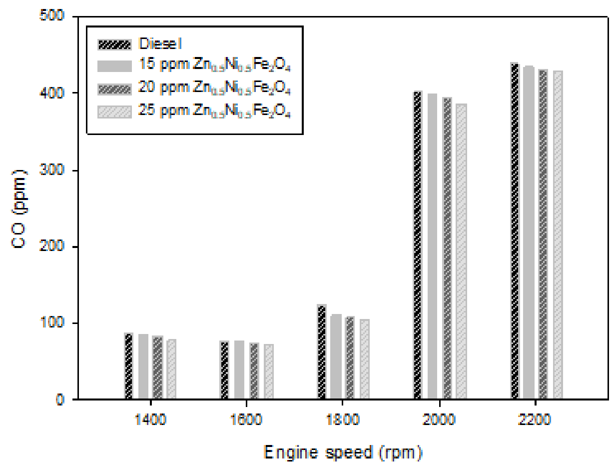

Figure 8. CO emissions of $Zn_{0.5}Ni_{0.5}Fe_2O_4$-diesel blends at different engine speeds

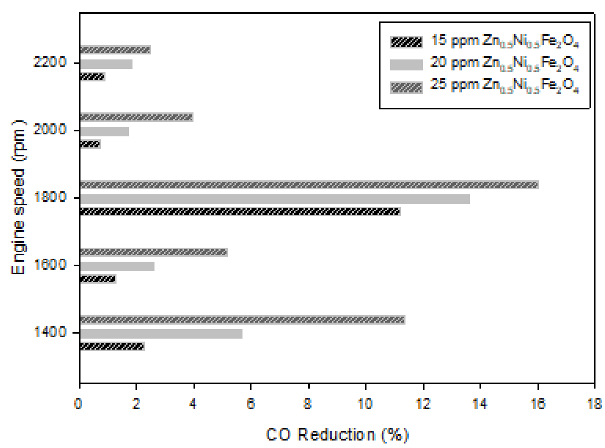

Figure 9. Percentage alteration of CO emissions of test fuels compared to diesel fuel

respect to diesel fuel. The maximum CO emission reduction was get at between 1400 and 1800 rpm engine speed. The average reduction is 3.3%, 5.1% and 7.8% with respect to diesel at the addition dosage of 15, 20 and 25 ppm respectively. The reason for the carbon monoxide emission is incomplete combustion, which is raised by a lack of oxidants, residence time, and temperature. The CO emissions decrease slightly with the use of nanoparticle additives. This may be owing to the catalytic activity of nanoparticles and improving the fuel–air mixing in the combustion chamber, and in turn resulting in reduced CO emissions [19]. Table 7 shows the changes in CO emissions with the addition of nanoparticle to diesel fuel at different engine speeds.

3.4. HC Emissions

The hydrocarbon (HC) emissions of modified test fuels is given in Figure 10. $NiFe_2O_4$ nanoparticle additive amount of 15, 20 and 25 ppm decreased the HC emissions values of the diesel fuel. Figure 11 gives percentage alteration of HC emissions of test fuels compared to neat diesel fuel. The average reduction in HC emissions is 3.3%, 4.4% and 5.2% with respect to neat diesel at the $NiFe_2O_4$ nanoparticle addition dosage of 15, 20 and 25 ppm respectively.

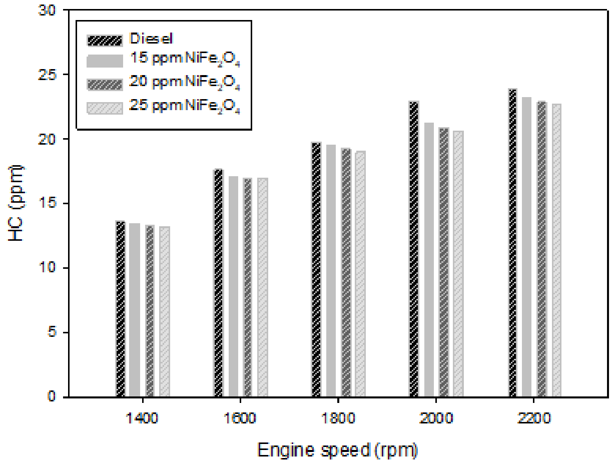

Figure 10. Impacts of $NiFe_2O_4$-diesel blends on HC Emission

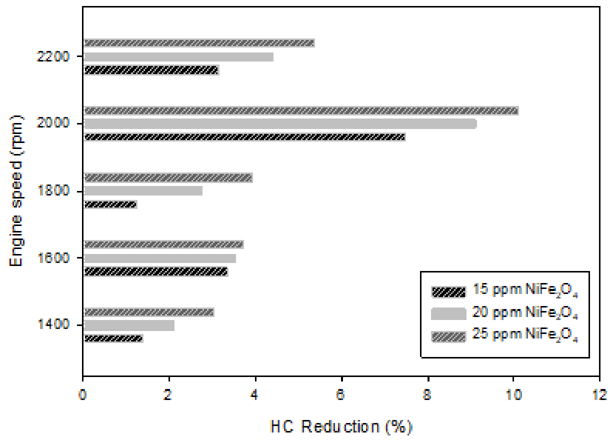

Figure 11. Percentage alteration of HC emissions of test fuels compared to diesel fuel

Hydrocarbon emission values of test fuels at different engine speeds are given in Figure 12. $Zn_{0.5}Ni_{0.5}Fe_2O_4$ nanoparticle additive decreased the HC emissions values of the diesel fuel. The average reduction is 2.8%, 3.6% and 5.4% according to neat diesel at the $Zn_{0.5}Ni_{0.5}Fe_2O_4$ nanoparticle addition dosage of 15, 20 and 25 ppm respectively. The average reduction in HC emission values decreased with the increased dosage of $Zn_{0.5}Ni_{0.5}Fe_2O_4$ nanoparticle addition to diesel fuel. HC emissions contribute to the formation of smog and may include photo chemically reactive species as well as carcinogens. Nano additive addition has been shown to decrease HC emissions. Reduction in HC emissions may be due to secondary atomization, shorten ignition delay, and catalytic activity of nano additives leading to better combustion [20].

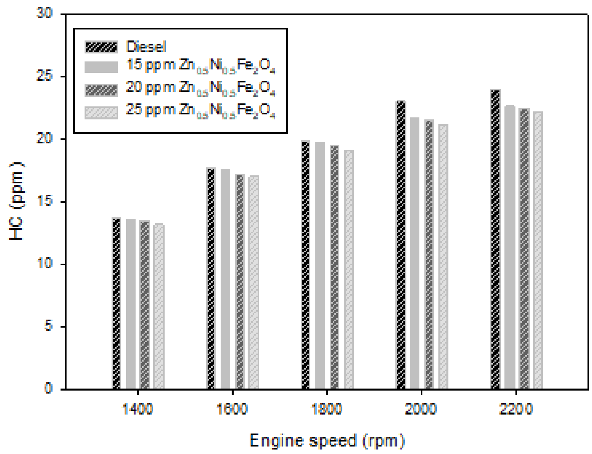

Figure 12. Effect of $Zn_{0.5}Ni_{0.5}Fe_2O_4$-diesel blends on HC emission

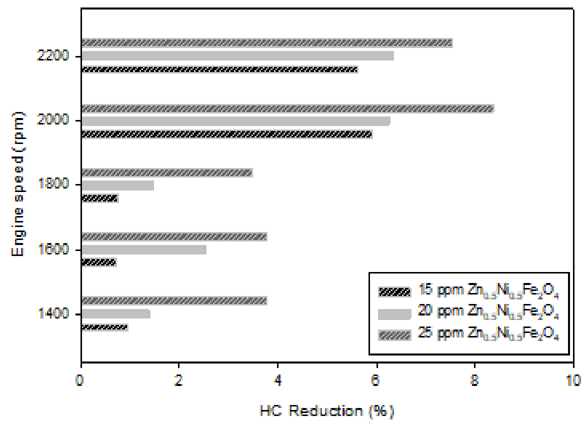

Figure 13. Percentage alteration of HC emissions of test fuels compared to diesel fuel

Table 8 demonstrates the changes in HC emissions with the addition of nanoparticle to diesel fuel at different engine speed.

4. Conclusions

In this experimental study the effects of $NiFe_2O_4$

Table 8. The changes in HC emissions with the addition of nanoparticles to diesel engine

		$NiFe_2O_4$-diesel fuel blends		
rpm	Diesel	15 ppm $NiFe_2O_4$	20 ppm $NiFe_2O_4$	25 ppm $NiFe_2O_4$
1400	13.64	13.4500	13.3500	13.2250
1600	17.65	17.0580	17.0230	16.9950
1800	19.8	19.5520	19.2560	19.0210
2000	22.98	21.2580	20.8850	20.6650
2200	23.95	23.1950	22.8970	22.6680
		$Zn_{0.5}Ni_{0.5}Fe_2O_4$-diesel fuel blends		
rpm	Diesel	15ppm $Zn_{0.5}Ni_{0.5}Fe_2O_4$	20ppm $Zn_{0.5}Ni_{0.5}Fe_2O_4$	25ppm $Zn_{0.5}Ni_{0.5}Fe_2O_4$
1400	13.64	13.51	13.450	13.125
1600	17.65	17.52	17.200	16.985
1800	19.8	19.65	19.510	19.110
2000	22.98	21.62	21.540	21.056
2200	23.95	22.6	22.430	22.142

and $Zn_{0.5}Ni_{0.5}Fe_2O_4$ nanoparticle addition to diesel fuel on exhaust emissions of 4 Stroke-6 cylinder turbocharged diesel engine. The results are given below:

- The NOx emission values decrease with the addition both nanoparticle additives. However, $NiFe_2O_4$ shows better effect in reducing NOx emissions.
- The maximum reduction on CO emission was achieved with $NiFe_2O_4$ nanoparticle addition at the dosage level of 25 ppm to diesel fuel.
- HC emissions of diesel were obtained to decrease with the addition of $NiFe_2O_4$ and $Zn_{0.5}Ni_{0.5}Fe_2O_4$ nanoparticles. The maximum reduction was found $Zn_{0.5}Ni_{0.5}Fe_2O_4$ nanoparticle at the addition dosage level of 25 ppm as 5.4 %.
- Overall $NiFe_2O_4$ and $Zn_{0.5}Ni_{0.5}Fe_2O_4$ nanoparticle addition to diesel fuel decreases the exhaust emissions this may be due to the in promoting fuel atomization and its favorable intrinsic catalytic effect, the level of harmful pollutants (such as HC, CO, NOx) in exhaust gases is appreciably reduced to varying degrees [21].

Nomenclature

$NiFe_2O_4$	: nickel iron oxide
$Zn_{0.5}Ni_{0.5}Fe_2O_4$	: nickel zinc iron oxide
SCR	:Selective catalytic reduction
NO_x	: nitrogen oxide
CO	: carbon monoxide
HC	: hydrocarbon

5. References

1. V.K. Kaimal, and P. Vijayabalan, "An investigation on the effects of using DEE additive in a DI diesel engine fueled with waste plastic oil", Fuel, 180, 90-96, 2016.
2. R.R. Sahoo, and A. Jain, "Experimental analysis of nanofuel additives with magnetic fuel conditioning for diesel engine performance and emissions", Fuel, 236, 365-372, 2019.
3. S. Karthikeyan, T.P. Dharma, A. Prathima, "Environment effect of La2O3 nano-additives on microalgae-biodiesel fueled CRDI engine with conventional diesel", Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 40(2), 179–185, 2018.
4. A.H. Zhang, C.S. Cheung, T.L. Chan, and C.D. Yao, "Experimental investigation of regulated and unregulated emissions from a diesel engine fueled with Euro V diesel fuel and fumigation methanol", Atmospheric Environment, 44, 1054–1061, 2010.
5. F. Aksoy, A. Uyumaz, F. Boz, and E. Yılmaz, "Experimental Investigation of Neutralized Waste Cooking Oil Biodiesel/Diesel Mixture and Diesel Fuel in a Diesel Engine at Different Engine Loads", International Journal of Automotive Science and Technology, 1(1), pp. 7-15, 2017.
6. D. Kannan, and W. Christraj, "Emission analysis of Azolla methyl ester with Bi_2O_3 nano additives for IC engine", Energy Sources, Part A: Recovery, Utilization, and Envi-ronmental Effects, 40(10), 1183–1189, 2018.
7. S.S. Hoseini, G. Najafi, B. Ghobadian, R. Mamat, M.T. Ebadi, and T. Yusaf, "Novel environmentally friendly fuel: The effects of nanographene oxide additives on the performance and emission characteristics of diesel engines fuelled with Ailanthus altissima biodiesel", Renewable Energy, 125, 283-294, 2018.

8. Ş. Yıldızhan, and A. Yaşar, "Performance and Emission Characteristics of Diesel Engine Operating on Biodiesel and Biodiesel Blended with Methanol and Propanol", International Journal of Scientific and Technological Research, 1(1), 270-278, 2015.
9. Q. Wu, X. Xie, Y. Wang, and T. Roskilly, "Effect of carbon coated aluminum nanoparticles as additive to biodiesel diesel blends on performance and emission characteristics of diesel engine", Applied Energy, 221, 597–604, 2018.
10. B. Sungur, B. Topaloglu, and H. Ozcan, "Effects of nanoparticle additives to diesel on the combustion performance and emissions of a flame tube boiler", Energy, 113, 44-51, 2016.
11. P. Karthikeyan, and G. Viswanath, "Effect of titanium oxide nanoparticles in tamanu biodiesel operated in a two-cylinder diesel engine", Materials Today: Proceedings, 22, 776-780, 2020.
12. P.M. Rastogi, A. Sharma, and N. Kumar, "Effect of CuO nanoparticles concentration on the performance and emission characteristics of the diesel engine running on jojoba (Simmondsia Chinensis) biodiesel", Fuel, 286, 119358, 2021.
13. C. Srinidhi, A. Madhusudhan, and S.V. Channapattana, "Effect of NiO nanoparticles on performance and emission characteristics at various injection timings using biodiesel-diesel blends", Fuel, 235, 185-193, 2019.
14. T. Özgür, M. Özcanli, and K. Aydin, "Investigation of Nanoparticle Additives to Biodiesel for Improvement of the Performance and Exhaust Emissions in a Compression Ignition Engine", International Journal of Green Energy, 12, 51–56, 2015.
15. M. Mehregan, and M. Moghiman, "Effects of nano-additives on pollutants emission and engine performance in a urea-SCR equipped diesel engine fueled with blended-biodiesel", Fuel, 222, 402-406, 2018.
16. J.S. Kumar, B.R.R. Bapu, and R. Gugan, "Emission examination on nanoparticle blended diesel in constant speed diesel engine", Petroleum Science and Technology, 38(2), 98–105, 2020.
17. T. Özgür. E.Tosun, C. Özgür, G. Tüccar, and K. Aydın, "Effect of MgO nanoparticule additives on performance and exhaust emissions of diesel fuelled compression ignition engine", MATTER: International Journal of Science and Technology, 3(3), 72-85, 2017.
18. T. Ozgur, G. Tuccar, E. Uludamar, A.C. Yilmaz, C. Güngör, M. Ozcanli, H. Serin, and K. Aydın, "Effect of nanoparticule additives on NOx emissions of diesel fueled compression ignition", Int. J. Global Warming, 7(4), 487-498, 2015.
19. M.A. Lenin, M.R. Swaminathan, and G. Kumaresan, "Performance and emission characteristics of a DI diesel engine with a nanofuel additive", Fuel, 109, 362-365, 2013.
20. J.S. Basha, and R.B. Anand, "An Experimental Study in a CI Engine Using Nanoadditive Blended Water–Diesel Emulsion Fuel", International Journal of Green Energy, 8, 332–348, 2011.
21. D. Mei, X. Li, Q. Wu, and P. Sun, "Role of cerium oxide nanoparticles as diesel additives in combustion efficiency Improvements and emission reduction", Journal of Energy Engineering, 142 (4), 2016.