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Experimental Study of the Influence of Nanoparticles Additive to Diesel Fuel on the Emission Characteristics

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Abstract

The present experimental work is conducted to examine the influence of adding Alumina (Al2O3) nanoparticles and Titanium oxide (TiO2) nanoparticles each alone to diesel fuel on the characteristic of the emissions. The size of both Alumina and Titanium oxide nanoparticles which have been added to diesel fuel to obtain nano-fuel is about 20 nm and 25 nm respectively. Three doses of (Al2O3) and (TiO2) were prepared (25, 50 and 100) ppm. The nanoparticles mixed with gas oil fuel by mechanical homogenous (manual electrical mixer) and ultrasonic processor. The study reveals that the adding of Aluminum oxide (Al2O3) and Titanium oxide (TiO2) to gas oil (Al2O3+DF) and (TiO2+DF) improves the emissions characteristic of engine such as CO emissions are reduced by 34.28% and 20.5% for TiO2+DF and Al2O3+DF respectively at 25ppm, the emissions of CO2 increased by about 1.75% and 2.27% for TiO2+DF and Al2O3+DF respectively at 100ppm, the emissions of NOx decreased by about 37.7% and 12.2% for TiO2+DF and Al2O3+DF respectively at 25ppm and the emissions UHC decreased by about 16.9% and 13.5% for TiO2+DF and Al2O3+DF respectively at 25ppm.

Keywords: *Alumina, diesel, emission characteristic, nanofuel, titanium oxide.*

1. Introduction

Diesel fuel is one of the world's largest sources of pollutants, where the burning of diesel fuel in compression ignition engine producing unburned hydrocarbons (UHC), nitrogen oxides (NO_x) and carbon monoxide (CO). Additionally, produce small amounts of sulfur oxides (SO_x) [1]. However it also, produces carbon dioxide (CO_2) which is a friend of the environment, oxygen (O_2) and water vapor (H_2O). So the researchers using several additives to diesel fuel especially the nanoparticles in recent years to resolve the problem of emissions [2]. The nano-fuel can define as a mixture of both diesel fuel and dosage of nanoparticles, which has different properties than net diesel and called also modified diesel.[3] The studies have shown that the addition of nanoparticles enhances the performance of the engine such as reducing specific fuel consumption and increasing thermal efficiency [4].The enhancement of the surface to volume ratio due to adding nanoparticles leads to decreasing the concentration of pollutants and increasing the rate of reaction [5].The expect reason of making the reaction faster due to a short delay period comparing to pure diesel [6]. Nanoparticles are worked to enhance some physical properties of a lot of fluids including diesel fuel [7].Where, it has been noticed that the nano additive to diesel (nanoparticles+ diesel) improve the fire point, flash point, viscosity, density and the other properties depending on the doses of nanoparticles [8].The particles which are suspended in diesel fuel increase effective thermal conductivity, the surface area of contact [9].Also, reducing the exhaust emission such as unburned Hydrocarbons (UHC), Nitrogen oxides (NO_x) and Carbon monoxides (CO) [10]. This present experimental research will study the influence of Alumina (Al_2O_3) and Titanium oxide (TiO2) nanoparticles on the emission characteristics. Although utilizing nanoparticles in diesel fuel have several advantages, the utilizing nanoparticles may involve several disadvantages such as increase in pumping power, higher viscosity (undesirable level) and block the nozzles due to agglomerate the nanoparticles [11]. There are many types of nanoparticles [12]; these are shown in the table (1).

Table1,
Types of Nanoparticles

No	Nanoparticle	Examples
1	Metal	ferric chloride ($FeCl_3$), Iron and Aluminum
2	Metal Oxides	Alumina, Cerium oxide, Zinc Oxide, MnO, TiO_2
3	Organic additives	Glycerin
4	Magnetic Nano fluid	Ferro fluids
5	Composite material	Alloyed nanoparticle, a170Cu30
6	Carbon nanotube	Tic, Sic
7	Layered	$Al+Al_2O_3$, Cu+C
8	Nitride ceramics	SiN, AIN
9	Earth oxide	CeO_2

2. Experimental Setup

The engine used in the experimental tests is Fiat diesel engine, four cylinders, 4-stroke, direct injection, natural aspirated, closed water-cooled cycle with a displacement volume (3.666 L) and fitted with a hydraulic dynamometer. Figure (2.1) shows the test engine with its equipment. The specifications of engine test are given in table (2). The type of additive nanoparticles is Alumina (Al_2O_3) and Titanium oxide (TiO_2). The selection of doses depends on primary experimental results and researchers' results [13]. The chosen doses are (25, 50, and 100) ppm. The size of both Alumina and Titanium oxide nanoparticles is 20 nm and 25 nm respectively. The nanoparticles blended with fuel each one by mechanical homogenous (manual electrical mixer) for one hour in order to prevent the gathering of particles rapidly and ultrasonic processor UP200Ht (power 200W and frequency 26 kHz) to disperse the nanoparticles and distribute them equally in the base fuel. All the exhaust gases emissions from the engine studied (unburnt Hydrocarbon (UHC), CO_2, CO and NOx) are measured by using the gas analyzer. The gas analyzer model AIRREX HG-550 used to measure the exhaust emission by two principles which are Electro-Chemical principle for measuring NOx and O_2 and non-dispersive infrared principle for measuring (UHC, CO_2, and CO).

The measurements for thermophysical properties of nano diesel and diesel are shown in table (3). Where the viscosity, density and the flash point and fire point were measured for both diesel and nano-diesel at University of Technology/ Department of Chemical Engineering. Cetane number was measured for both diesel and nano-diesel at University of Babylon / Department of Polymer Engineering. The calorific value of diesel and nano-diesel was measured at Middle Refineries Company/ Quality Control Laboratories Department.

Fig. 1. The test engine.

Fig. 2. Gas Analyzer.

Table 2,
Tested Engine Specification.

Engine model	TD 313 Diesel engine reg
Engine type	Four-cylinder, four-stroke
Displacement	3.666 L
Bore	100 mm
Stroke	110 mm
Compression ratio	17/1
Fuel injection pump	Unit pump 26 mm diameter plunger
Static injection timing	23 BTDC
Spray angle of nozzle	160o
Nozzle hole diameter	0.48 mm
Nozzle opening pressure	40Mpa

Table 3,
Thermophysical properties of nano diesel.

Sample	**Density (kg/m^3)**	**Dynamic viscosity *10^{-3} (kg/m.s)**	**Flash point & Fire point ^oC**	**Calorific Value k Cal/kg**	**Cetane number**
Diesel (D)	844.3	2.788	65-70	10941.08	51.8
D+Al_2O_3 25 ppm	845.8	2.810	71-75	10943.23	52.1
D+Al_2O_3 50 ppm	846.8	2.806	74-77	10946.33	53.1
D+$Al_2O_3$100ppm	849	2.823	76-79	10949.41	53.9
D+TiO_2 25 ppm	852.4	2.780	73-76	10950.73	51.9
D+TiO_2 50 ppm	853	2.791	75-78	10955.78	52.7
D+TiO_2 100 ppm	853.8	2.825	78-82	10960.43	53.2

3. Result and Discussion

This section introduces the results obtained from experiments, where the results include:

3.1 Carbon Monoxide (CO) Emission

The influence of nanoparticles doses level and types on CO emission for diesel fuel is shown in figure (2) and figure (3).The figures reveal that the CO emission decreases with adding TiO_2 and Al_2O_3 nanoparticles; especially with TiO_2 may be because of the delay period of titanium oxide is shorter than alumina which leads to complete combustion [10]. The best dose of nanoparticles is 25ppm for both types. Where, TiO_2 and Al_2O_3 reduce the emissions of CO by 34.28% and 20.5% at 25ppm and 75% load respectively.

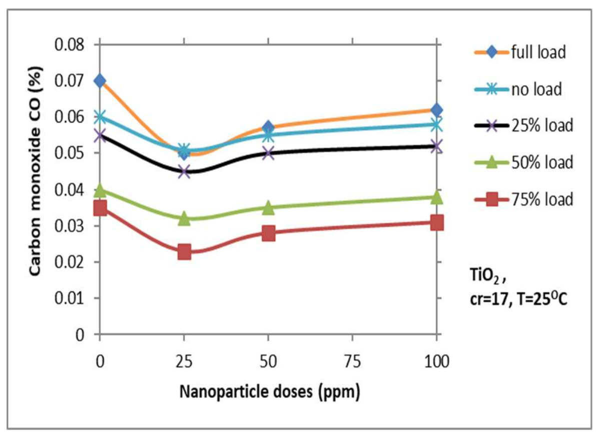

Fig. 3. variation of the carbon monoxide with Titanium nanoparticles doses.

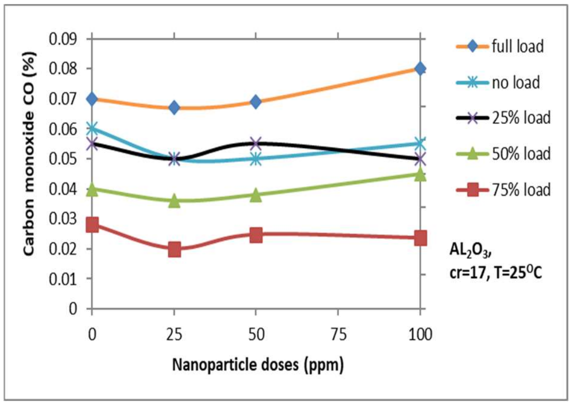

Fig. 4. variation of the carbon monoxide with Alumina nanoparticles doses.

3.2 Nitrogen Oxides (NO_x) Emission

The influence of nanoparticles doses level and types on NO_x emission for diesel fuel is shown in figure (4) and figure (5).The two figures reveal that the NO_x emission decreases with adding the dose 25 ppm of TiO_2 nanoparticles at all loads. While, the dose 25 ppm of Al_2O_3 decreased NO_x emission at low loads. The expected reason for increased NO_x is high temperature with Aluminum and the availability of oxygen. Furthermore, the thermal conductivity of Al_2O_3 is larger than TiO_2 by four times approximately. Where, the thermal conductivity of TiO_2 and Al_2O_3 are 9W/m.K and 40W/m.K respectively. The biggest decrease of NO_x emission with Al_2O_3 and TiO_2 is 12.2% and 37.7% with no load at 25 ppm.

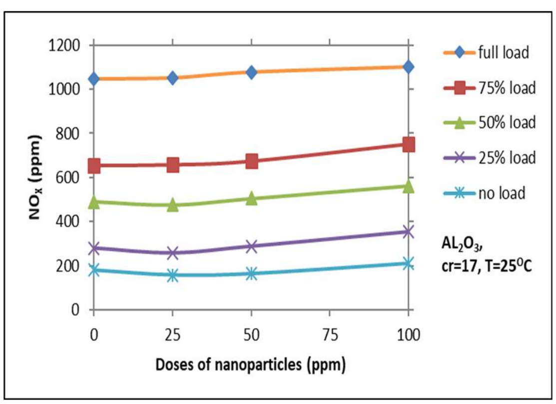

Fig. 5. Variation of Nitrogen Oxide Emissions (NOx) with Alumina nanoparticles doses.

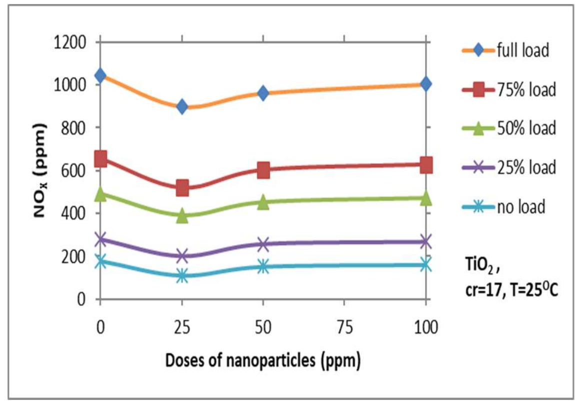

Fig. 6. Variation of Nitrogen Oxide Emissions (NOx) with Titanium nanoparticles doses.

3.3 Carbon Dioxide Emissions (CO_2)

Figure (6) and figure (7) shows the variation of Carbon dioxide emission (CO_2) with Nanoparticles doses for two types (TiO_2 and Al_2O_3). These figures reveal that CO_2 emissions increase by increasing the dose of Nanoparticles due to high thermal conductivity and the presence of oxygen in nanoparticles which in turn makes the combustion complete. The best increase was obtained in CO_2 emissions for TiO_2 and Al_2O_3 by 1.75% and 2.27% at 75% load with 100 ppm respectively. The increasing of CO_2 emissions gives an indication to decrease CO emissions. The overlap between the two curves of no-load with the curve with load with nanoparticles dose variation due to rich mixture at full load which in turn cause a reduction in CO2 so the overlap occurred.

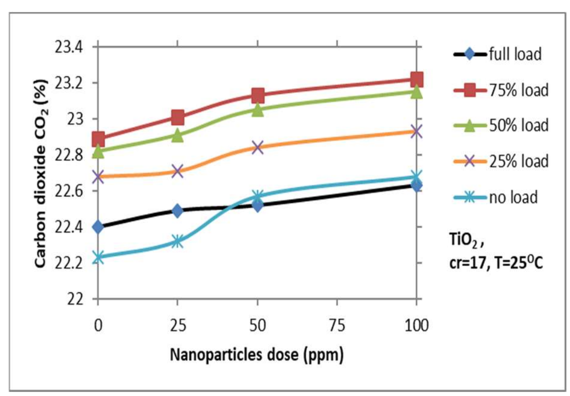

Fig. 7. Variation of Carbon dioxide Emissions (CO_2) with Titanium nanoparticles doses.

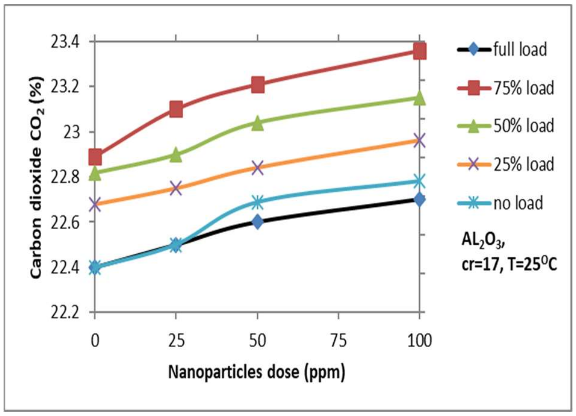

Fig. 8. Variation of Carbon dioxide Emissions (CO_2) with Alumina nanoparticles doses.

3.4 Unburnt Hydrocarbon (UHC) Emissions

The variation of unburnt hydrocarbon emissions (UHC) with different doses of nanoparticles for two types (Al_2O_3 and TiO_2) is shown in figure (8) and figure (9).The two figures reveal that UHC emissions decrease by adding any dose of Al_2O_3 nanoparticles at no load and it is increased with all other loads. While the additive TiO_2 nanoparticles decrease the emissions of UHC with all loads at all doses including no-load state. The expect reasons, that the equivalence ratio of TiO_2 is less than Al_2O_3 , incomplete combustion of (D+ Al_2O_3) and the size TiO_2 larger than Al_2O_3 that gives a greater chance to atomize the large droplets of fuel during entering. Finally, the biggest doze was 25 ppm for all loads.

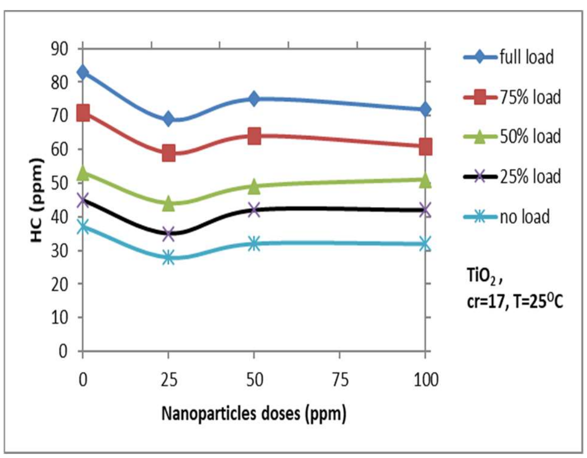

Fig. 9. Unburnt Hydrocarbon Emissions (UHC) with Titanium nanoparticles doses.

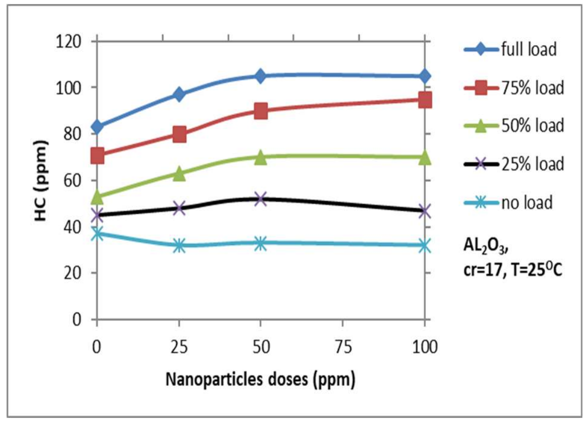

Fig. 10. Unburnt Hydrocarbon Emissions (UHC) with Alumina nanoparticles doses.

4. Conclusion

The present paper focuses on the effect of adding Alumina and Titanium oxide to diesel fuel with variable doses on the emission characteristics based on the experimental results from present work. Accordingly, the following conclusions are:

1. The best reduction of CO at 25 ppm for both types. Where TiO_2 and Al_2O_3 reduce the emissions of CO by 34.28% and 20.5% at 25ppm and 75% load respectively.
2. The adding of TiO_2 decrease NO_x emission by 37.7% at 25 ppm. While adding Al_2O_3 increase NO_x emission except at low loads, where NO_x emission decreased by 12.2% at 25 ppm.
3. The adding of nanoparticles increase CO_2 emission for both types. The best increase achieves in CO_2 emissions for TiO_2 and Al_2O_3 by 1.75% and 2.27% at 75% load with 100 ppm respectively.
4. The adding of TiO_2 decrease UHC emission by16.9% at 25 ppm and 75% load. While adding Al_2O_3 increase UHC emission except with no load, where UHC emission decreased by 13.5% at 25 ppm.

5. References

[1] Amer Abdullah, Abed Al-Khadim M. Hassan, Mahmoud A.Mashkour "The effect of bio-additives on the burning velocity and emission of liquid hydrocarbon fuel" Ph.D.thesis dissertation Department of Mechanical Engineering/University of Technology, 2018.

[2] Rolvin D. "Silvaa, Binu K.G, Thirumaleshwara Bhat" Performance and

Emission characteristics of a C.I. Engine fuelled with diesel and TiO2 nanoparticles as fuel additive" St Joseph Engineering College, Vamanjoor, Mangaluru 575028, Karnataka, India,2015.

[3] Hamzah H. K., “Experemental and Numerical Investigation of Turbulent Forced Convection in A Circular Pipe with Induced Vibration”, Ph.D. Thesis dissertation Department of Mechanical Engineering/ University of Babylon, 2016.

[4] Mahendravarman R. D.B. Sivakumar, P. Sivakumar. “Experimental study on performance and emission characteristics of a direct injection compression ignition engine with fe3O4 nanoparticles”. Advanceds in Natural and Applied Sciences. 10(4): pages 139-144, 2016.

[5] S Karthikeyan, A Elango, A prathima "Diesel engine performance and emission analysis using canola oil methyl ester with the nano sized zinc oxide particles" Indian Journal of Engineering and Material Science, Vol.21, pp. 83-87, 2014.

[6] Arul M.S. V,Anand R.B., Udayakumar M. “Effects of cerium oxide nanoparticle addition in diesel and diesel-biodiesel-ethanol blends on the performance and emission characteristics of a CI engine”. ARPN Journal of Engineering Applied Sciences, Vol 4, NO.7, 2009.

[7] Nithin Samuel, Muhammed Shefeek “Performance and Emission Characteristics of a C.I Engine with Cerium Oxide Nanoparticles as Additive to Diesel" International Journal of Science and Research Vol.4 Issue 7, 2013.

[8] Sukkar, K., Karamalluh, A., & Jaber, T. (2019). Rheological and Thermal Properties of Lubricating Oil Enhanced by the Effect of CuO and TiO2 Nano-Additives. Al-Khwarizmi Engineering Journal, 15(2), 24-33. https://doi.org/10.22153/kej.2019.12.002.

[9] Chaichan, M., Hussein, R., & Jawad, A. (2017). Thermal Conductivity Enhancement of Iraqi Origin Paraffin Wax by Nano-Alumina. Al-Khwarizmi Engineering Journal, 13(3), 83-90. https://doi.org/10.22153/kej.2017.02.003.

[10] S P Venkatesan, P N Kadiresh "Influence of aluminum oxide nanoparticle additive on performance and exhaust emissions of diesel engine" International Journal of Applied Engineering Research ISSN 0973-4562 Vol.10, Number 3 pp. 5741-5749, 2015.

[11] Ajay K. "Effects of cerium oxide nanoparticles on compression ignition performance and emission characrastics when using water diesel emulsion". Thesis M.Sc. dissertation Department of Mechanical Engineering/ Thapar University Patiala-147004, India July 2014.

[12] Yimin X., and Qiang L., “Heat transfer enhancement of nanofluids”, International Journal of Heat and Fluid Flow. Vol. 21, pp.58-64, 2000.

[13] Hayder Abed Dhahad, Sinan Abdul-Ghafar Ali "Experimental study on The Effect of nanoparticle addition on the pressure at the start of ignition, maximum pressure and timing of maximum pressure" ARPN Journal of Engineering and Applied Sciences, ISSN 1819-6608, Vol. 14, NO.8, 2019.

دراسة تجريبية لتأثير الجسيمات النانوية المضافة لوقود الديزل على خصائص الانبعاث

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الخلاصة

تم إجراء العمل التجريبي الحالي لفحص تأثير إضافة جزيئات الألومينا (Al_2O_3) النانوية وجسيمات أكسيد التيتانيوم (TiO_2) النانوية كل على حدة إلى وقود الديزل على خصائص الانبعاثات. يبلغ حجم كل من الألومينا وأكسيد التيتانيوم اللذان تمت إضافتهما إلى وقود الديزل للحصول على وقود النانو حوالي ٢٠ نانومتر و ٢٥ نانومتر على التوالي. تم تحضير ثلاث جرعات من (Al_2O_3) و (TiO_2) وهي (25، 50، 100) جزء في المليون. تم خلط الجسيمات النانوية بوقود زيت الغاز بواسطة معالج ميكانيكي متجانس (خلاط كهربائي يدوي) ومعالج فوق صوتي. كشفت الدراسة أن إضافة أكسيد الألومنيوم (Al_2O_3) وأكسيد التيتانيوم (TiO_2) إلى زيت الغاز (Al_2O_3+ DF) و (TiO_2+ DF) يحسن من خصائص انبعاثات المحرك مثل انبعاثات ثاني أكسيد الكربون بنسبة ٣٤,٢٨٪ و ٢٠,٥٪ بالنسبة إلى (TiO_2+ DF) و (Al_2O_3+ DF) على التوالي عند ٢٥ جزء في المليون ، زادت انبعاثات ثاني أكسيد الكربون بحوالي ١,٧٥٪ و ٢,٢٧٪ ل (TiO_2+ DF) و (Al_2O_3+ DF) على التوالي عند ١٠٠ جزء في المليون ، وانخفضت انبعاثات أكاسيد النيتروجين بحوالي ٣٧,٧٪ و ١٢,٢٪ لكل من (TiO_2+ DF) و (Al_2O_3+ DF) على التوالي عند ٢٥ جزء في المليون وانخفضت انبعاثات (UHC) بحوالي ١٦,٩٪ و ١٣,٥٪ لكل من (TiO_2+ DF) و (Al_2O_3+ DF) على التوالي عند ٢٥ جزء في المليون.