Engineering and Technology Journal
Journal homepage: engtechjournal.org

Experimental Investigation of the Influence of Adding Alumina to Diesel Fuel on the Engine Performance and Emission Characteristics

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Submitted: 29/07/2019 Accepted: 24/09/2019 Published: 25/04/2020

K E Y W O R D S

Diesel, Alumina, nanoparticles, performance, emission characteristics.

A B S T R A C T

The present experimental work is conducted to examine the influence of adding Alumina (Al2O3) nanoparticles to diesel fuel on the characteristic of the emissions and engine performance. The size of nanoparticles which have been added to diesel fuel to obtain nano-fuel is 20 nm. Three doses of Aluminum oxide were prepared (25, 50 and 100) ppm. The nanoparticles mixed with fuel by mechanical homogenous (manual electrical mixer) and ultrasonic processor. The study reveals that the adding of Aluminum oxide (Al2O3) to gas oil (Al2O3+DF) enhances the physical properties of fuel. Also, the adding of (Al2O3) reduce CO emissions by 20.5%, decrease NOx emission by 12.2%, increasing CO2 emissions by about 2.27% and decrease UHC emission about 13.5%. Furthermore, reduces the brake specific fuel consumption by 14.3%, decreasing the equivalence ratio by14.87% and improving the brake thermal efficiency by about 10.89%.

How to cite this article: S. T. Bunyan and A. A. K. M. Hassan, "Experimental investigation of the influence of adding alumina to diesel fuel on the engine performance and emission characteristics," Engineering and Technology Journal, Vol. 38, Part A, No. 04, pp. 523-529, 2020.
DOI: https://doi.org/10.30684/etj.v38i4A.498

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 (NOx) and carbon monoxide (CO). Additionally, produce small amounts of sulfur oxides (SOx) [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 studies have shown that the addition of nanoparticles enhances the performance of the engine such as reducing specific fuel consumption and increasing thermal efficiency [3].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 [4].The expect reason of making the reaction faster due to a short delay period comparing to pure diesel [5]. Nanoparticles are worked to enhance some physical properties of a lot of fluids including diesel fuel [6].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 [7].The particles which are suspended in diesel fuel increase effective thermal conductivity, the surface area of contact [8].Also, reducing the exhaust emission such as unburned Hydrocarbons (UHC), Nitrogen oxides (NOx) and Carbon monoxides (CO) [9]. This present experimental research will study the influence of Alumina nanoparticles (Al_2O_3) on the engine performance and emission characteristics.

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 1 shows the test engine with its equipment. The specifications of engine test are given in Table 2. The adding nanoparticles dosage is (25, 50 and 100) ppm and the size of Alumina nanoparticles is 20 nm. The nanoparticles mixed with fuel 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 1. Where the viscosity, density and the flash point and fire point were measured for both diesel and nano-diesel at University 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.

Although using nanoparticles in diesel fuel have several advantages, it may include disadvantage such as [8]:

I. Higher viscosity: the increasing of dosage of nanoparticles in the suspension will increase the viscosity to undesirable level.

II. Increase in pressure drop and pumping power: The increasing of nanoparticles size will increase the pressure drop, therefore, increasing the power required to fuel pumping.

III. Probability of agglomerate the nanoparticles into large particles which in turn causes blockage the hole of nozzle.

Figure 1: The test engine

Table 1: Thermophysical properties of nano diesel

Sample	Density (kg/m^3)	Dynamic viscosity *10^{-3} (kg/m.s)	Flash point & Fire point ^{O}C	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_3 100 ppm	849	2.823	76-79	10949.41	53.9

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

3. Results and discussion

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

I. Emissions of the Engine

These sub-sections reveal the result of the variation of exhaust emissions before and after adding nanoparticles:

a) Carbon Monoxide (CO)

Figure 2 reveals that the CO emissions decrease with adding Al_2O_3 nanoparticles because of the delay period of became shorter with adding Alumina which leads to complete combustion [10]. The best dose of nanoparticles was 25ppm. Where, the adding of Alumina reduces the emissions of CO by 20.5% at 25ppm.

b) Emissions of Nitrogen Oxides (NO_x)

Figure 3 reveals that the NO_x emission increase with adding Alumina because the thermal conductivity of Al_2O_3 is very large compared with base diesel fuel which in turn leads to raising the temperature. But the adding of the dose 25 ppm of Al_2O_3 decreased NO_x emission at low loads because of low temperature. The biggest decrease in NO_x emissions with Al_2O_3 was 12.2% at 25 ppm.

c) Carbon Dioxide Emissions (CO_2)

Figure 4 reveals that CO_2 emissions increase by increasing the dose of nanoparticles Alumina due to high thermal conductivity and presence of oxygen in nanoparticles which in turn makes the combustion complete. The best increase was obtained in CO_2 emissions for Al_2O_3 was 2.27% at 100 ppm.

d) Unburnt Hydrocarbon(UHC) Emissions

Figure 5 reveals that UHC emissions decrease by adding any dose of Al_2O_3 nanoparticles at no load and it is increased with all other loads due to high equivalence ratio.

II. Performance of the Engine

These sub-sections reveal the result of the variation of engine performance before and after adding nanoparticles:

a) Brake Specific Fuel Consumption (B.S.F.C)

Figure 6 reveals that the addition of Al_2O_3 nanoparticles decrease specific fuel consumption with any dose for all speeds because the increasing of Al_2O_3 leads to increase calorific value (LCV) and the Alumina nanoparticles supply oxygen which plays an important role in making the combustion complete and releasing a maximum possible heat. The best dose of nanoparticles was 25 ppm.

b) Equivalence ratio (φ)

Figure 7 reveals that the additive nanoparticle decreases the equivalence ratio (φ). Because the increase in calorific value leads to decreasing fuel consumption which in turn leads to decreasing the equivalence ratio (φ). The biggest obtained reduction of the equivalence ratio (φ) was 14.87% at dose 25 ppm.

c) Brake Thermal Efficiency (η_{bth})

Figure 8 reveals that brake thermal efficiency increases by adding Alumina nanoparticles due to better combustion which resulted from the increasing of surface to volume ratio. The best dose has been obtained was 25 ppm. Where, the improvement of brake thermal efficiency was 10.89% at 25 ppm.

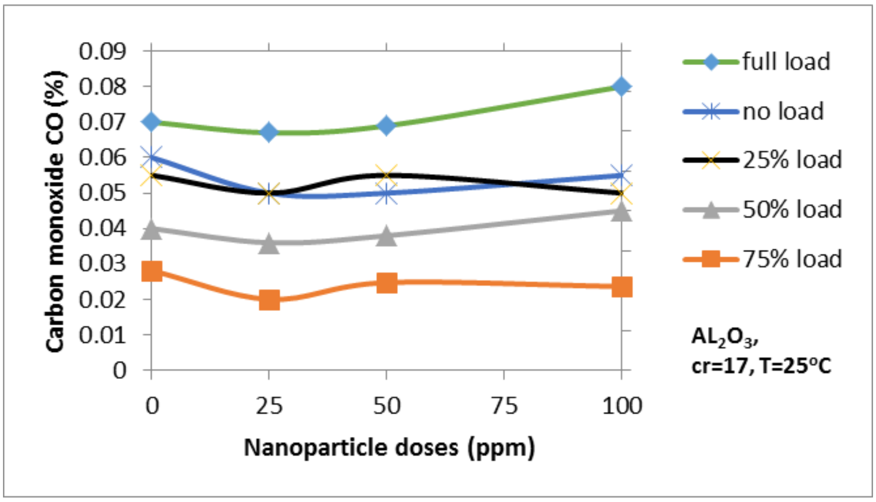

Figure 2: Variation of the carbon monoxide with Alumina nanoparticles doses

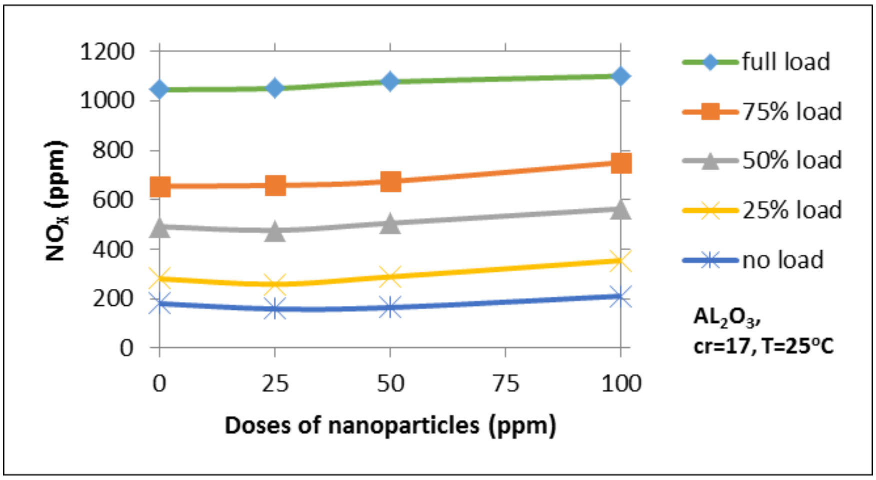

Fig 3: Variation of Nitrogen Oxide Emissions (NOx) with nanoparticles doses

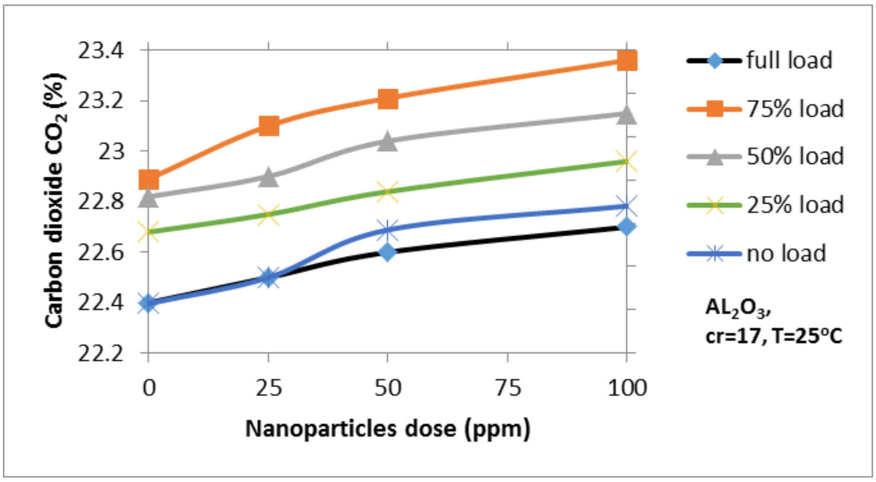

Fig 4: Variation of Carbon dioxide Emissions (CO2) with nanoparticles doses

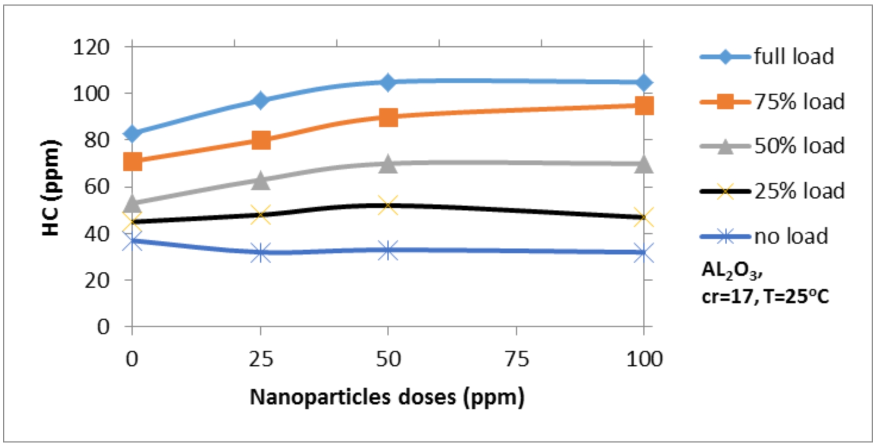

Figure 5: Variation of Unburnt Hydrocarbon (HC) with doses

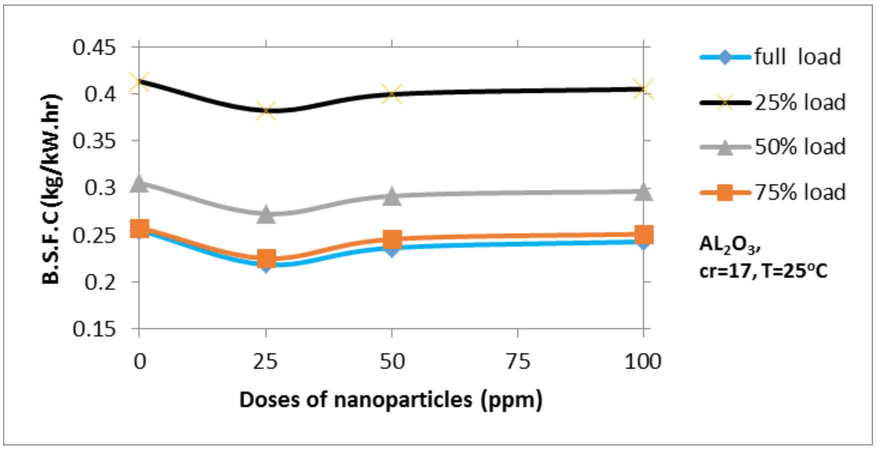

Figure 6: Variation of Brake Specific Fuel Consumption (B.S.F.C) with dose

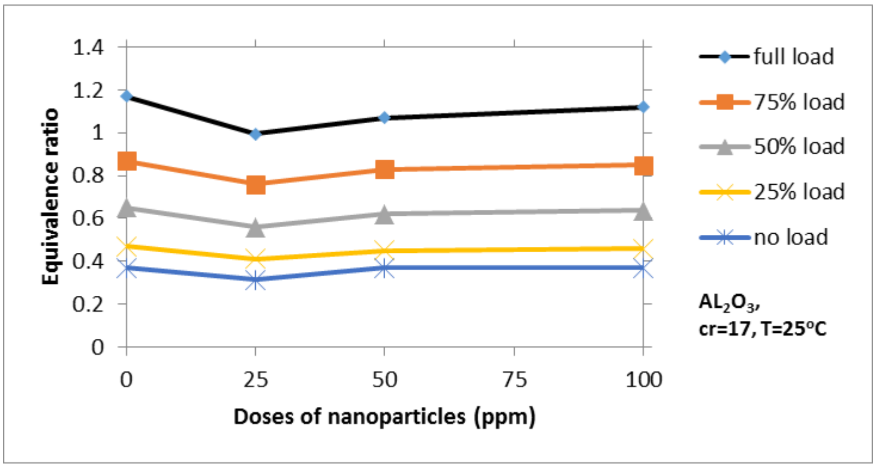

Figure 7: Variation Equivalence ratio (φ) with nanoparticles doses

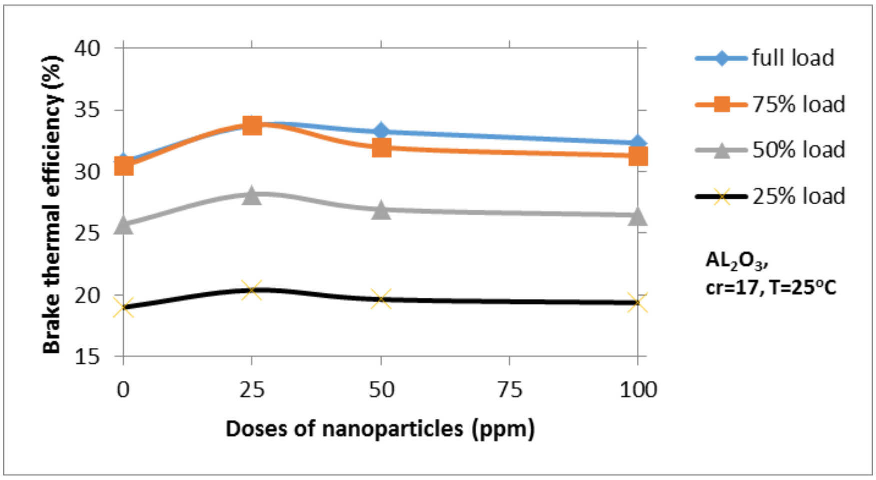

Figure 8: Variation of brake thermal efficiency with doses

4. Conclusions

The present research focuses on the effect of adding Alumina to diesel fuel with variable doses on the emission characteristics and engine performance based on the experimental results from present work. Accordingly, the flowing conclusions are:

I. Emission Parameters

a) The best reduction of CO was at 25 ppm. Where, Alumina Al_2O_3 reduces the emissions of CO by 20.5% at 25ppm and 75% load.
b) The adding of Alumina (Al_2O_3) increase NO_x emission except the low loads, where NO_x emissions decrease by 12.2% at 25 ppm with no load.
c) The increasing dosage level of Alumina nanoparticles increases CO_2 emissions. The best increase achieves in CO_2 emissions was 2.27% at 75% load with 100 ppm.
d) The adding of Alumina (Al_2O_3) Nanoparticles increase UHC emission except with no load, where UHC emission decreases by 13.5% at 25 ppm with no load.

II. Performance of Engine

a) The adding of Alumina (Al_2O_3) Nanoparticles decreases the brake specific fuel consumption. The best reduction of B.S.F.C was 14.3% at 25ppm and full load.
b) The adding of nanoparticles decrease equivalence ratio. Where, the equivalence ratio decreased about 14.87% at 25 ppm with full load.
The brake thermal efficiency increases with adding nanoparticles. The best improvement of brake thermal efficiency was 10.89% for 75% load at 25 ppm.

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