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

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ABSTRACT 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%.


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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 (CO2) which is a friend of the environment, oxygen (O2) and water vapor (H2O). 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 expected reason of making the reaction faster due to a short delay period comparing to pure diesel [5]. Nanoparticles are used 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 (Al₂O₃) 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), CO₂, 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 O₂ and non-dispersive infrared principle for measuring (UHC, CO₂, 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

<table>
<thead>
<tr>
<th>Sample</th>
<th>Density (kg/m³)</th>
<th>Dynamic viscosity *10⁻³ (kg/m.s)</th>
<th>Flash point &amp; Fire point ºC</th>
<th>Calorific Value k Cal/kg</th>
<th>Cetane number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel (D)</td>
<td>844.3</td>
<td>2.788</td>
<td>65-70</td>
<td>10941.08</td>
<td>51.8</td>
</tr>
<tr>
<td>D+Al₂O₃ 25 ppm</td>
<td>845.8</td>
<td>2.810</td>
<td>71-75</td>
<td>10943.23</td>
<td>52.1</td>
</tr>
<tr>
<td>D+Al₂O₃ 50 ppm</td>
<td>846.8</td>
<td>2.806</td>
<td>74-77</td>
<td>10946.33</td>
<td>53.1</td>
</tr>
<tr>
<td>D+Al₂O₃ 100 ppm</td>
<td>849</td>
<td>2.823</td>
<td>76-79</td>
<td>10949.41</td>
<td>53.9</td>
</tr>
</tbody>
</table>

### Table 2: Tested Engine Specification

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

### 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 Al₂O₃ 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 (NOₓ)

Figure 3 reveals that the NOₓ emission increase with adding Alumina because the thermal conductivity of Al₂O₃ 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 Al₂O₃ decreased NOₓ emission at low loads because of low temperature. The biggest decrease in NOₓ emissions with Al₂O₃ was 12.2% at 25 ppm.

c) Carbon Dioxide Emissions (CO₂)

Figure 4 reveals that CO₂ 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 CO₂ emissions for Al₂O₃ was 2.27% at 100 ppm.

d) Unburnt Hydrocarbon(UHC) Emissions

Figure 5 reveals that UHC emissions decrease by adding any dose of Al₂O₃ 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 Al₂O₃ nanoparticles decrease specific fuel consumption with any dose for all speeds because the increasing of Al₂O₃ 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 (η₉₇₉₉)
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](image1)

![Figure 3: Variation of Nitrogen Oxide Emissions (NOₓ) with nanoparticles doses](image2)
Figure 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
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 $\text{Al}_2\text{O}_3$ reduces the emissions of CO by 20.5% at 25ppm and 75% load.

b) The adding of Alumina ($\text{Al}_2\text{O}_3$) 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 ($\text{Al}_2\text{O}_3$) 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 ($\text{Al}_2\text{O}_3$) 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.
References


