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Effect of Aluminum Oxide Nanoparticles Fuel Additives on the Performance and Emissions of Diesel Engine

***Abstract**- The effect of Aluminum Oxide (AL_2O_3) nanoparticles fuel additives on the performance and emission characteristics of diesel engine was investigates. Diesel fuel was mixed with the (AL_2O_3) nanoparticles in the mass fractions of 100 and 150 ppm by using ultrasonicator. Direct injection (DI), by using fiat diesel engine that run at fixed speed (1500 rpm) and constant fuel injection pressure (400 bar) with varying the operation load. The gain result was likening with those obtain when the operation the diesel engine with normal fuel. Measurements indicated that there is enhancement in the thermal efficiency and the brake specific fuel consumption with increasing the dosing level of (AL_2O_3) nanoparticles in the blended fuel. The emission results at all loads showed that NOx and smoke produced by (AL_2O_3) blended fuels were less than those produced by diesel fuel. Diesel fuel produced CO and HC more than (AL_2O_3) blended fuels at high load and less at low load.*

***Keywords**- Nanoparticles Fuel Additives; Combustion; Diesel Engine; Gases Emissions*

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1. Introduction

The As a result of increased consumption of fossil fuels and increased air pollution as well as increased the cost of extraction the oil and refining, encouraged researchers to find alternative fuel or use catalysts additive to the fuels [1-4]. Biodiesel is one of the important alternative fuels but unfortunately this alternative fuel did not reduce the harmful emission such as NO_x, CO, and HC. Moreover, fuel consumption is more than from use the neat diesel especially at high load. To solve problem of pollution and reduce the fuel consumption, some researchers use nanometal as the catalysts additive to diesel fuel or to the biodiesel. Fangsuwannarak et al. [5] investigated the effect of titanium oxide nanoparticles addition to the diesel fuel, and showed when used the nanoparticles enhancement the brake thermal efficiency and lower brake specific fuel consumption and reduce emission of the NO_x, HC and smoke opacity but increase the value of CO. Sajeevan et al. [6] used the cerium oxide nanoparticles blended to the diesel fuel, they found improving in the brake thermal efficiency and reduce emission of the NO_x and HC. Shafil et al. [7] showed an enhancement in brake thermal efficiency and reduce the brake specific fuel consumption and exhaust emission drooping in NOx emission but rise in CO when ferrofluid nanoparticles additive was used. Kao et al. [8] used aluminum nanoparticles additive to the diesel fuel, they showed lower value of brake specific fuel consumption and reduction in emission of the NO_x and smoke opacity. Lenin et al. [9] investigated the result of two kinds of nanoparticles manganese oxide and copper oxide blended with diesel fuel, they showed improving in brake thermal efficiency and reduce emission of the NO_x, CO and HC, they also showed that the manganese oxide is bestead than copper oxide. Hamadi et al. [10], used the zinc oxide nanoparticles blended with diesel fuel, they found enhancement in thermal efficiency and drooping in brake specific fuel consumption, they also found drooping in emission of NO_x, CO and HC especially at high load. Roshith et al. [11], used aluminum oxide and cobalt oxide nanoparticles blended with refined diesel and diesel with some traditional additives, resulted reduction in peak pressure, heat release rate and enhancement in brake thermal efficiency and reduced in emission for NO_x, HC, CO and smoke opacity. Mohan et al. [12], studied the effect of aluminum oxide as nanoparticles additive to the diesel fuel, and showed enhancement in exhaust gases temperature so that enhancement in thermal efficiency, reduction in specific fuel consumption and reduction in emission characteristic for CO and HC, but slightly increase in NO_x emission. Bobu and Raja [13], obtian improved thermal efficiency, reduced in NO_x emission and reduced

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smoke opacity by using the aluminum oxide nanoparticles blended with diesel fuel. Venkatesan [14], enhanced the brake thermal efficiency and reduction in emission of the HC, NO_x, smoke, and CO by using the Aluminum oxide nanoparticles blended with diesel fuel.

The aim of this work is to investigate the effect of nanoparticle aluminum oxide (Al_2O_3) blended with diesel fuel at the ratio 100 ppm and 150 ppm on the combustion characteristics and emission of NO_x, CO, smoke Number and HC. The study was achived at fixed engine speed (1500 rpm) and constant injection pressure (400 bar) with various operation load (BMEP) (06, 1.2, 2.4, 3, 3.5 bar)

2. Experimental setup

The engine and the measurement instruments had been used in the experiments was explained in detail in a previous research of the same author [10], Figure 1. The preparation of the fuel which contain the alumina nanoparticles of 100 and 150 ppm fractions of mass with the aid of ultrasonicator. The ultrasonic is used to disperse the nanoparticles in a base liquid, as it destroys the feasible agglomerate particles [15].

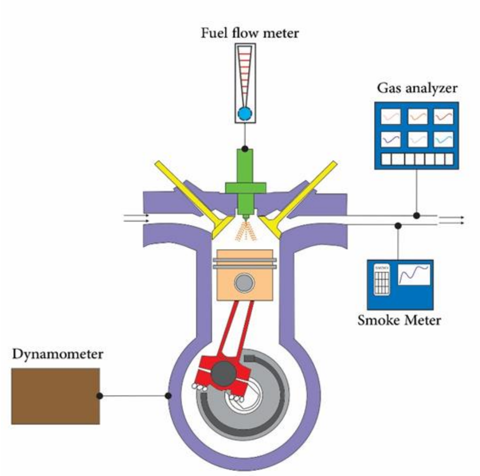

Figure 1: Schematic of the rig

Nomenclature

AL_2O_3	Aluminum Oxide
BMEP	Brake Mean Effective Pressure
BSFC	Brake Specific Fuel Consumption
CO	Carbon monoxide
CO_2	Carbon dioxide
HC	hydrocarbon
NO_x	Nitric oxides
ppm	parts per million

3- Results and Discussions

I. Engine performance

1. Brake specific fuel consumption

Figure 2 display the brake specific fuel consumption (b.s.f.c) variation with load (brake mean effective pressure). Generally, there is a reducing in the BSFC with a rise in engine load, the increase in (b.s.f.c) at low load is an effect of the insufficient combustion of fuel. It can be view that the BSFC values for Al_2O_3 100 and Al_2O_3 150 blends was less than that of individual diesel fuel. The BSFC decrease with increasing in Al_2O_3 dosing level, the average reduction of (b.f.s.c) when addition nanoparticles is (7.14% and 14.06%) for the dosing level 100 and 150 ppm respectively. This effect may be due to the increase of the evaporation rates, which is led to reduction in the ignition delay with increasing of nanoparticles level by virtue of enhanced surface area to volume ratio which produce to more sufficient combustion [10], in addition to the enhancement in calorific value with increasing of nanoparticles level [16].

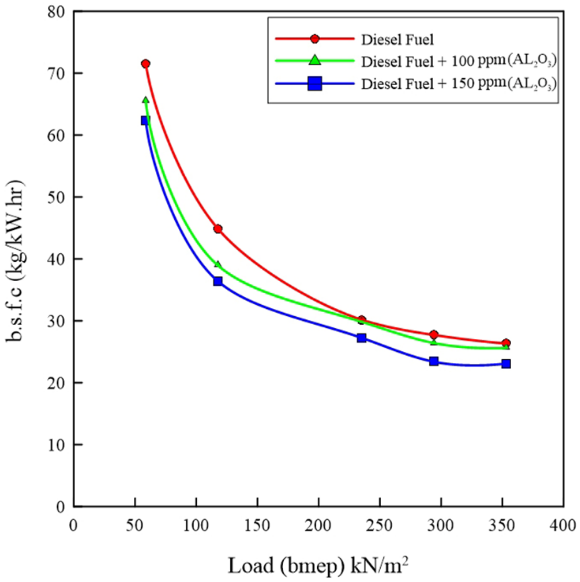

Figure 2: The brake specific fuel consumption (BSFC) at different loads for three types of fuels

2. Brake thermal efficiency

Figure 3 shows the thermal efficiency with load. The thermal efficiency of the engine could be improved with increasing the load because the increase the temperature will lead to enhancement in the combustion prosses and, thus, increase the brake thermal efficiency. If the aluminum oxide (AL_2O_3) blended with diesel fuel led to increase the calorific value as discussed in previous section. The aluminum oxide additives produce decrease ignition delay and higher heat release rates which improve break thermal efficiency. The average improvement of thermal efficiency is (5.21% and 15.91%) for the dosing level for the dosing level 100 and 150 ppm respectively.

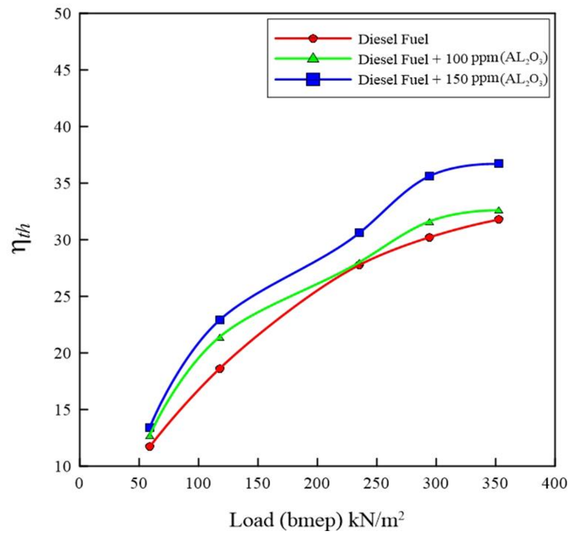

Figure 3: The brake thermal efficiency at different loads for three types of fuels.

II. Emission characteristics

1. Nitric Oxides (NO_X)

The result of NO_X variation with load is seen in Figure 4, for all fuel type when rising engine load the engine temperature is increase, the NO_x emission is strong relationship with temperature and therefore when rising the engine load increase the NO_x emission. Also, NOx emissions decrease with Al_2O_3 level increase at all operation loads and the average decreases of NO_x is (6.66% and 7.57%) for the dosing level for the dosing level 100 and 150 ppm respectively. Adding the nanoparticles of Al_2O_3 reduce the value of NOx at all load. As mentioned in performance results, the ignition delay reduced with using Al_2O_3 blended fuels compared to diesel fuel. The shorter ignition delay of Al_2O_3 blends leads to reduction the premixed burn fraction (PMBF) of combustion and this will reduce the combustion temperature which leads to decrease the NOx emissions [1].

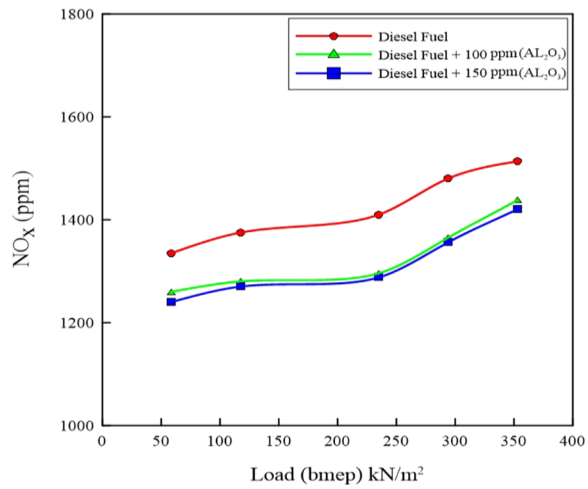

Figure 4: The NO_X at different loads for three types of fuels.

2. Smoke Number

Figure 5 display that emission of smoke No. of the Al_2O_3 blends fuel is less than of diesel fuel. The reduction of smoke number with Al_2O_3 blends fuel may be due to founded more oxygen content so that reduce the smoke number especially at the diffusion stage of combustion and when rising the load the smoke number is more reduction when fuel is blended with nanoparticle because of more fuel burned in the diffusion phase because the nanoparticles act as catalysts for the oxidation reaction. So the average reduction of smoke number for dosing level 100 and 150 ppm is (22.63% and 25.84%) respectively

3. Carbon Monoxide (CO)

Figure 6 shows the emission of CO. the result show when increase the load reduce the value of CO because increase the value of fuel ratio and increase temperature in the combustion chamber all that may lead to unstable react of the combustion, so that Co cannot continuously react into Co_2. The carbon monoxide concentration appears to freeze leading to Co emission [9]. The addition of Al_2O_3 decrease the CO emissions especially at high load, 150 ppm of Al_2O_3 shows the lower CO values and the average reduction of CO is (8.42% and 17.21%) for the dosing level for the dosing level 100 and 150 ppm respectively. The increase amount of oxygen that founded in Al_2O_3 enhancement the combustion process that lead to less fuel rich zone formation; consequently, the CO emission decreases, in addition to being a catalyst.

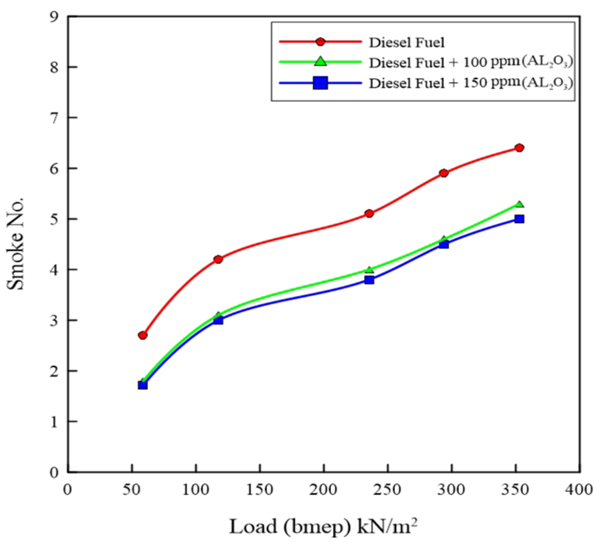

Figure 5: The Smoke NO at different loads for three types of fuels.

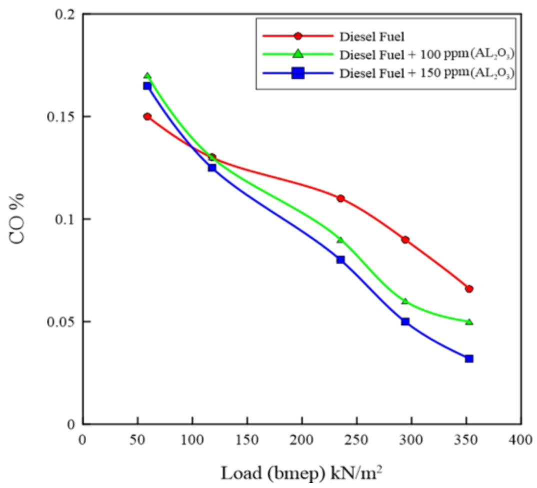

Figure 6: The CO at different loads for three types of fuels

4. Hydro Carbon (HC)

The HC emission shown in Figure 7. Both CO and HC emissions are the products of incomplete combustion and they tend to decrease with load increase. The total hydrocarbon emissions are generally formed as a result of flame quenching. The formation of higher CO and HC emissions are strongly related to the viscosity of fuel. Higher viscosity also leads to longer spray penetration. As a result, wetting of the cylinder walls eventually leads to the formation of higher CO and HC emissions by incomplete combustion. The lower emissions of CO and HC for Al_2O_3 blends fuels could be possibly attributed to the enriched combustion characteristics of nanoparticles leading to high catalytic activity because of their higher surface to volume ratio and improving fuel air mixing which leads to improve combustion. The average reduction of HC is (5.85% and 8.65%) for the dosing level for the dosing level 100 and 150 ppm respectively.

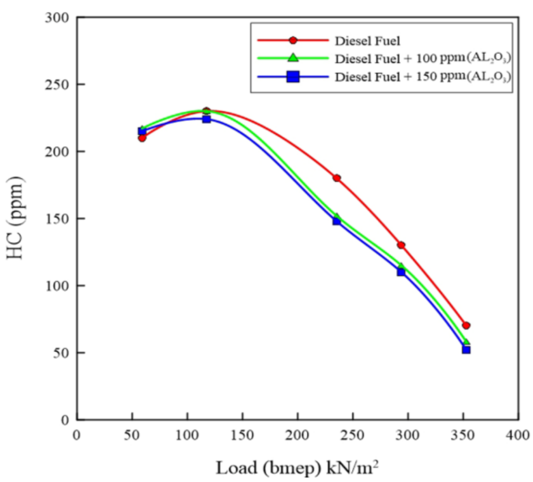

Figure 7: The HC at different loads for three types of fuels

4. Conclusions

The nanoparticle show a good catalyst when blended with fuel diesel. Nanoparticles of AL_2O_3 increase the surface to volume ratio and increase the calorific value, that's leading to reduction in ignition delay and extra completely combustion so blended diesel fuel with nanoparticles of AL_2O_3 show reduction in BSFC and enhancement in thermal efficiency and when increase the ratio of nanoparticle shows more reduction in b.s.f.c and thermal efficiency.

This improving in the combustion process and reduce the ignition delay leading to reduce the premixed burn fraction of combustion and reduce combustion temperature all that lead to reduce in NO_x emission and when increase the ratio of nanoparticle the more reduction in NO_x. the fuel blended with nanoparticle AL_2O_3 led to increase the amount of oxygen content and the nanoparticle acts as catalysts for the oxidation reaction this leading to reduction in smoke number and this reduction increase with increase the nanoparticle AL_2O_3 ratio.

CO and HC are lower for AL_2O_3 nanoparticles blended fuels, due to more catalytic activity because of their greater than surface to volume ratio and enhancement fuel air mixing which leads to improve combustion.

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