Enhancing the Performance and EmissioCharacteristics of Diesel Engine Using Modified Fuel by Addition of Aluminum Oxides to Biodiesel – Diesel Blend.

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Abstract

This present experimental work investigates the influence of nanoparticles added to biodiesel blend on the engine performance and emission characteristics. The nanofuel is prepared by adding the aluminum oxide (Al_2O_3) nanoparticle to biodiesel – diesel blend and compared with pure diesel and biodiesel –diesel blend. The effect of 25 ppm , 50 ppm , and 100 ppm of aluminum oxide(Al_2O_3) nanoparticles with size 25 nm , added to biodiesel blend are experimentally investigated in a diesel engine type(FIAT), four cylinder ,direct injection (DI), water cooled , and compression ratio 17 :1. with variable engine speed and load . The aluminum oxide was mixed with (BIO20%+DIESEL 80%) B20 fuel blend by the aid of ultrasonicator technique. The nanoparticles adding to B20 improved and increased the physical properties of nanofeul such as cetane number , calorific value , density , flash and fire point and viscosity. Improvement in engine performance is very clear with nanoparticles additives, the specific fuel consumption decreases by 15.5% for 25 ppm, 10.4% for 50 ppm and 6.13% for 100 ppm as compared with neat B20 at full load and all operation condition. The brake thermal efficiency increased by 20.8% for 25 ppm, 17.4 % for 50 ppm and 4% for 100 ppm as compared with neat B20 at full load and all operation condition. The exhaust temperature is reduced by 18.19 % for 25ppm , 17.15% for 50 ppm and 13.17% for 100 ppm .The emission results at all loads show a reduction of the (UHC) , (NO_X) and (CO) emission by 15.6% , 16% and 18.18% respectively for 25 ppm .

Keywords: Diesel, Biodiesel, Performance, Emission characteristics.

1. Introduction.

Diesel engine is one of the most used engines in the modern world, designed to work with fossil fuel . As a result of the increasing cost of fossil fuel extraction globally and the high emissions of it is used such as nitrogen oxides (NOX) , unburnt hydrocarbon (UHC) , carbon monoxide (CO) and carbon dioxide (CO2). All these emission, effect on the environment and human. It has become necessary to find low emission alternative fuel which has similar properties of diesel fuel. The world now seems to be using the biodiesel as an alternative to diesel fuel because of its lower exhaust emission and healthier properties due to high content of oxygen (10 -12%) [1,2]. The biodiesel can be mixed with the pure diesel at different ratio as a modified fuel [3]. Many researchers have shown that using of biodiesel – diesel blend in compression ignition engine can reduce all exhaust gas emissions but the nitrogen oxide emission may be increased[4] . On the other hand many researchers show that using metal nanoparticles additives to the biodiesel – diesel blend to improve the engine performance and reduced the exhaust emission , due to the nanoparticles properties which increases the surface area to volume ratio [5].

Hussain et.al [6] carried out experimental investigation on the effect of Iron oxide (Fe3O4) nanoparticle as dose with 10 ppm additive to pure diesel , (B20 , and B40). The nanofuel properties improved by additives the nanoparticles . increasing the brake thermal efficiency when increasing the concentration additive of iron oxide as compared with pure diesel, B20 and B40 without nanoparticles. The brake specific fuel consumption reduced with increasing the additive of the nanoparticles . Also a reduction in the exhaust emission such (UHC) , (NOX) and (CO) with increasing the doses of iron oxide (Fe3O4) nanoparticles.

C. Sayed Aalam et.al[7] investigated experimentally the effect of aluminum oxide (AL2O3) nanoparticles to the biodiesel (ZJME25) , using CRDI diesel engin . The nanoparticles were used in two doses 25 ppm and 50 ppm additive to biodiesel (ZIME25). The brake specific fuel consumption increased with (ZJME25) and reduced with increase the doses of nanoparticles. The brake thermal efficiency is reduced for (ZJME25) as compared with pure diesel , and increased with additive the nanoparticles. The, UHC , CO and smoke opacity decreases with (ZJME25) as compared with pure diesel , but the NOX increased slightly with (ZJNE25) .

Harish kumar et.al[8] carried out experimental investigation on the effect of aluminum oxide (Al2O3) nanoparticles additive to biodiesel blend (B20) on the performance .The concentration of nanoparticle additive was 0.25 g/l , 0.5 g/l ,0.75g/l and 1g/l ,and the size of nanoparticle was less than 50 nm. The specific fuel consumption decreased for 0.25 g/l and decreasing in the minimum value for 0.5 g/l . The better brake thermal efficiency and brake power were obtained at 0.5 g/l of Al2O3 additive to B20. They increased by 24.7% and 3.85 % respectively .

.Karthikeyan et.al [9] investigated experimental the effect of the nanoparticles zinc oxide (ZnO) additive to the canola oil methyl ester on engine performance and exhaust emission characteristic. The average diameter of nanoparticles used in this test is less than 100nm , and fuels used at different blended such as B20(80% diesel +20% canola oil methyl ester) ,D80 B20ZnO50 (80% diesel +20% canola oil methyl ester+50ppm ZnO) and D80B20ZnO100 (80% diesel + 20% canola oil methyl ester +100ppm ZnO) . The specification, of engine were single cylinder , four stroke, direct injection , air cooled, and constant speed at 1500rpm. The results of this study have increased the calorific value and kinematic viscosity for D80B20ZnO50PPM and D80 B20ZnO100PPM as compared with B20. Decreasing the ignition time delay for the ZnO additives fuels. Reduced the brake specific fuel consumption and increasing the brake thermal efficiency for the nanoparticles addition B20.

Shiva et. al [10] studied the effect of ferrofluid additive to B20 on the engine performance and exhaust emission. The ferrofluid additive to B20 was 0.5% , 1% and 1.5%by volume. The blend 1% of ferrofluid gave higher brake thermal efficiency and lower BSFC than the other blends. UHC and CO emission decresed with 1% ferrofluid additive to B20 by 22.9% and 35.8% respectively. The NOX emission was minimum for volume fraction by 1%.

2. Experimental Apparatuses.

The experimental setup consists of a Fiat diesel engine . Exhaust gas analyzer and Exhaust gas temperature measurement .A photograph and Schematics of the experimental setup are shown figures (1,) respectively . The engine used in this experiment is a four cylinder , water cooled , Direct injection , four stroke , natural aspirated , a cylinder bore of 100 mm and stroke 110mm , compression ratio 17:1, and the displacement volume 3666 cm3..

The engine coupled with a hydraulic dynamometer to measuring the power through which load was applied by increasing the torque. Table (1) shows the engine specification.

Figure (1) : A photograph of Engine Test.

Table (1): The Engine Specification.

Engine parameter	Value
Engine type	FIAT diesel engine 4 cylinder, 4 stroke
Engine model	TD 313 Diesel engine REG
Displacement volume	3666 cm^3
Combustion type	Direct injection, water cooled , natural aspirated
Valve per cylinder	(2)
Bore	100 mm
Stroke	110 mm
Compression ratio	17:1
Fuel injection pump	Unit pump 26 mm diameter plunger
Fuel injection nozzle	Nozzle hole diameter (0.48mm) . Spray angle 160°. Nozzle opening pressure 40 mpa

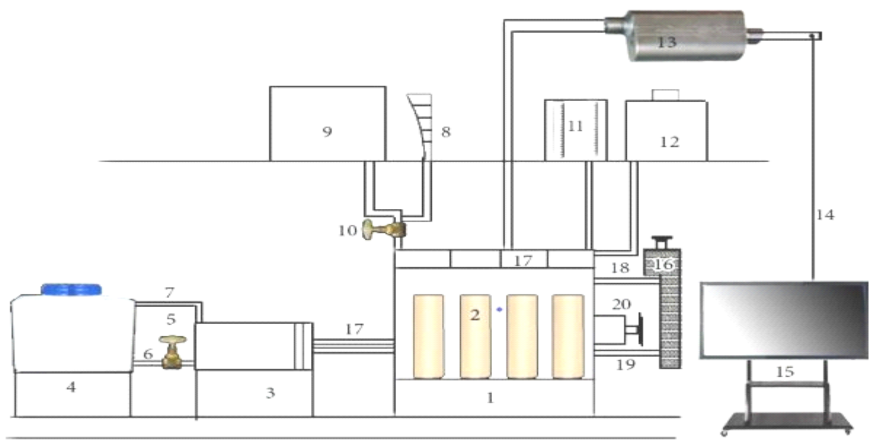

Figure (2) : Schematic diagram of experimental setup.

Table (2): Definition of Parts of The Schematic Diagram

1	Engine four cylinder	11	Water manometer
2	Cylinders	12	Air surge tank
3	Hydraulic Dynamometer	13	Exhaust
4	Water tank	14	Exhaust gas probe
5	Valve	15	Gas analyzer
6	Water inlet to dynamometer	16	Radiator
7	Water out from dynamometer	17	Cylinder head
8	Fuel flow meter	18	Water inlet to engine
9	Fuel tank	19	Water outlet from engine
10	Fuel tank valve	20	Engine fan

2. Nano fuel preparation .

In the present work , the ratio of biodiesel – diesel blend used is B20 (BIO 20% + Diesel 80) blend. The biodiesel used in this study is produces form sunflower oil by the Transesterification of fatty acids . The nanoparticles is aluminum oxide (Al2O3) at different doses 25 ppm , 50 ppm and 100 ppm . The nanoparticle size is 25 nm. The weight of the aluminum oxide (Al2O3) nanoparticles desired for each dose is calculated by the equation below. Table (3). shows the mass required additive on the five liter of fuel.

$$\varphi = \frac{\frac{m_p}{\rho_p}}{\frac{m_p}{\rho_p} + \frac{m_f}{\rho_f}}$$

Where φ the weight of nanoparticles wanted for each dose.

Mρ is the mass of the nanoparticles. **ρ**p is density of the nanoparticle.

Mf is mass of the fuel . ρf is density of the fuel

Table (3) : The Mass of Nanoparticles Required Additive for Each Dose.

Volume ratio of nanoparticles (ppm)	**Ø %**	**The mass of nanoparticles required for 5 liters**
25 ppm	0.0025	0.4933
50 ppm	0.005	0.9866
100 ppm	0.01	1.9732

The aluminum oxide (Al_2O_3) nanoparticles are weighed to a predefined mass fraction at 25 ppm , 50 ppm, and 100 ppm and dispersed in the neat B20 with the aid of mixer mechanical for 15 minutes in the first stage , to ensure the spreading of the nanoparticles in the fuel used and prevent sedimentation of the nanoparticles quickly in the neat B20 fuel. Figure (4) shows the mechanical mixer of the nanoparticles with B20 fuel blend .

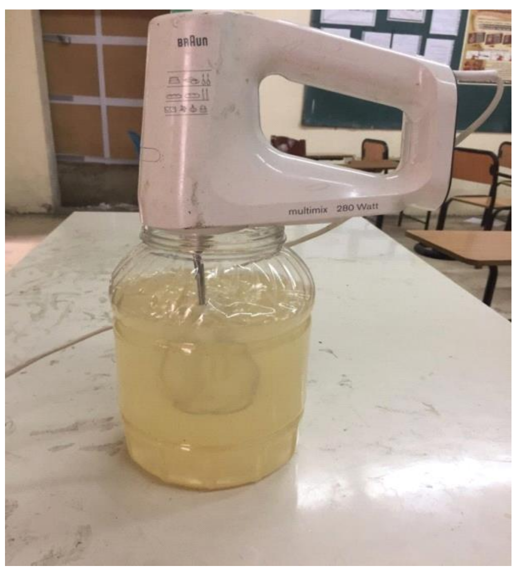

Figure (4). A photograph of Mixer Mechanical.

An ultrasonicater probe type (UP200 H t), is used after mechanical mixer to prevent the sedimentation and agglomeration of aluminum oxide (Al2O3) nanoparticles in the neat B20 fuel blend.

The ultrasonicator is a highly effective means of creating dispersion of nanoparticles in the fuel, and capable to remaining in suspension for a few weeks. The ultrasonic probe is immersed in the liquid fuel, and this probe generates a waves for time period of 20 minutes to suspension and uniform dispersion the nanoparticles in the liquid fuel . The modified fuel is utilized immediately for many days to prevent the settling or sedimentation that may occurring. The Ultrasonicator process are done in the (Center for nanotechnology research and advanced materials) – University of Technology as shown in figures (5), and (6) .

Figure (5) : Ultrasonicator Process

Figure (6) : Probe Sonicator.

Table (4) : The Properties of Nanofuel.

Fuel and Nano fuel	Viscosity Cp at27C°	Density kg/m^3	Flash&Fire point ^{0} C	Cetane number	Calorific value kJ/Kg
Pure diesel	2.778	844.3	65-70	51.8	45808
B20+D80	3.224	860.6	81-86	53.4	43431.9
B20+25 ppm Al_2O_3	3.3	866.2	83-87	53.8	43678.9
B20+50 ppm Al_2O_3	3.306	868	85-89	54.2	43821.3
B20+100 ppm Al_2O_3	3.322	870	87-90	54.4	43911.64

3. Measurement system of Engine.

3.1 Measurement of engine speed.

The engine speed is measured by a tachometer fitted to the engine as shown in figure (7). Also the engine speed is measured by another means of tachometer fitted to the engine shown in figure 8. For purpose of calibration.

Figure (7). Engine Tachometer.

Figure (8). Digital Tachometer.

3.2. Fuel consumption.

The volumetric fuel consumption is measured by using a glass bulb of known volume and the glass bulb having size indicator to know the fuel consumed as shown in figure (9). The time taken out of a stopwatch for discharges to a certain volume of fuel , the volume is divided by time to obtain the volumetric flow rate of fuel in ml/s which multiplied by the density of fuel to predict it in kg/s

3.3 Air consumption.

The air mass flow rate is measured by the engine manometer shown in figure (10) . The orifice of the air flow consumption measured by the difference between the atmosphere pressure and the intake pressure. For calculation of the air mass flow rate the following equation is used

$$\dot{m} = (12 \sqrt{\Delta h_o} \ / \ 3600) \ x \ \rho_a$$

Figure (9) : Engine Glass Bulb.

Figure (10) : Engine Manometer.

3.4 Exhaust Emission.

The exhaust gas analyzer type (HG-540/550) is used to the analysze and measure the emissions of the exhaust gases, as shown in the figure (11). The exhaust gas analyzer detected the NOX , HC , CO , CO2 and O2 cocenteration. The exhaust gases is picked up through the probe fitted on the exhaust pipe, and prevent moister from entering to the measurement cell by using special condensate filter. This device operate by an infrared ray that transmit and sent through the condensate filter to the measuring cell, and absorb the rays at different wavelengths and different concentration. The operation guide of the device must be followed, including power ON, ready state, insert prop to the exhaust outlet, measuring, pull out the prop and clean up after each reading.

3.5 Exhaust Gas Temperature.

The exhaust gas temperature is measured by using a thermocouple type (j) and with a digital reader. The measuring rod connected to the outer pipe of the exhaust manifold by the probe instrument to measure the exhaust temperature.as shown in figure (12).

Figure (11) : Gas Analyzer

Figure (12) : Exhaust Gas Temp.

4. Results and Discussions.

4.1 Effect of Nanoparticles Additive on Engine Performance.

4.1.1 Brake Specific Fuel Consumption.

Figure (13) illustrates the variation of Brake specific fuel consumption (BSFC) with increased the engine speed (rpm) and reduced the load, for various fuel blends. the Brake specific fuel consumption for the biodiesel –diesel blends seems to be high than the pure diesel , this because of decrease the calorific value and increase viscosity of the biodiesel blends as compared with the pure diesel ,This caused a large volume of fuel droplets after atomization which lead unproperly mixing with the air[9] .The brake specific fuel consumption (BSFC) for the (B20% + D80%) B20 is seems to be lower than B10 , B30, B40 and B50 . A suitable oxygen content and density that creates a complete combustion in (B20% +D80%) blends [7]. The increase in the specific fuel consumption (bsfc) is about (5.85%, 7.48% , 10.55 % , 14.3% , and 16.5) for (B20 , B10 , B30 , B40 and B50) ratios as compared with pure diesel at full load 80 kg and engine speed 1100 rpm.This results are in agreement with [7] ,[8].

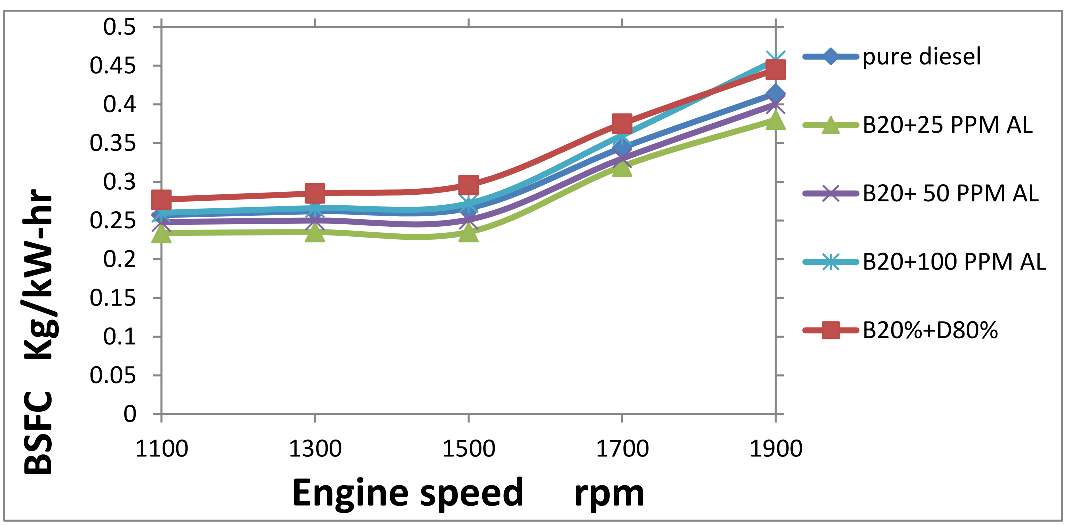

Figure (13): Variation of BSFC with Engine Speed.

4.1.2 Brake thermal efficiency.

The effect of nanoparticles additive to B20 fuel on brake thermal efficiency (BTE) is shown in figure (14) . It seems that the maximum value of brake thermal efficiency (BTE) is obtained for (B20 +25 PPM AL) , as compared with the neat B20 blends fuel. The additives nanoparticles reduce the evaporation period and hence reduce ignition delay due to higher thermal conductivity of aluminum oxide nanoparticles (AL2O3). This causing high heat transfers rate through the ignition time delay [7] . It can also be observed from the graph that (B20 +25PPM AL) is better brake thermal efficiency for all conditions. The (B20+25 PPM AL) at full load increased about 20.8% as compared with to neat B20 fuel blends . The percent's of increases of BTE are 17.4% and 4% for (B20+50 PPM AL) and (B20+100PPM AL) respectively as compared with the neat B20 fuel blends. The brake thermal efficiency (BTE) for (B20 +100 ppm AL) is still less than pure diesel. This due to the increasing of nanoparticles doses caused incomplete turbulence level of the fuel blends , which makes improper blends of fuel that caused incomplete combustion [13]. It is clear that the (B20 +25 PPM AL) is optimum performance fuel blends.

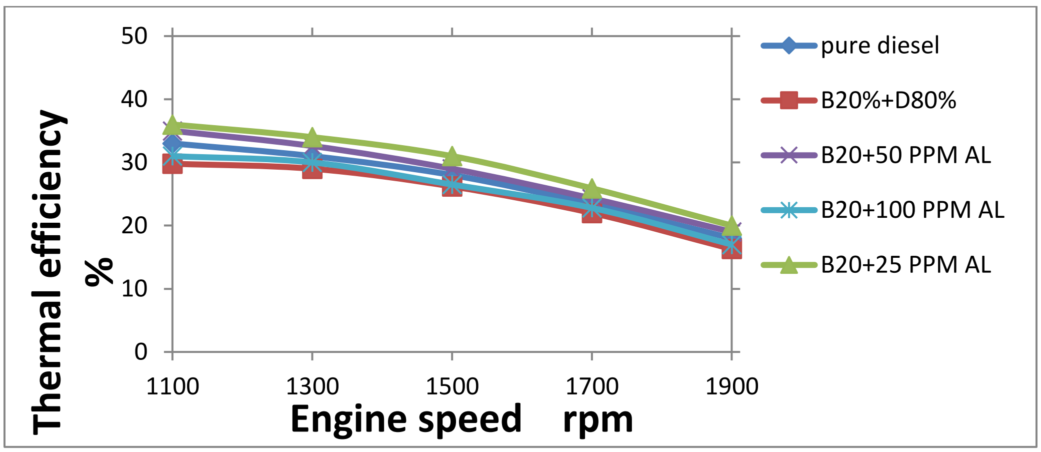

Figure (14): Variation of Thermal Efficiency with Engine Speed.

4.1.3 Exhaust Gas Temperature.

Figure (15) shows the effect of nanoparticles additive on Exhaust gas temperature with variation of engine speed and loads. The dosage level of nanoparticles 25 ppm Al, shows lower exhaust temperature than the other fuels at full loads. This is due to the nanoparticles additives caused reduction in the ignition time delay and increasing the cetane number therefore the major part of combustion completed before the (TDC) , that leads to better combustion. In addition the nanoparticles increases the surface area to volume ratio [6] , and this caused reduction to the exhaust gas temperature. The percent reduction of exhaust gas temperature for (B20+25PPM Al) at full loads as compared with neat B20 is 18.19% . The percentage 17.15% and 13.17% reduction of EGT for (B20 +50PPM Al) and (B20+ 100 PPM Al) respectively with the neat B20 fuel blends.

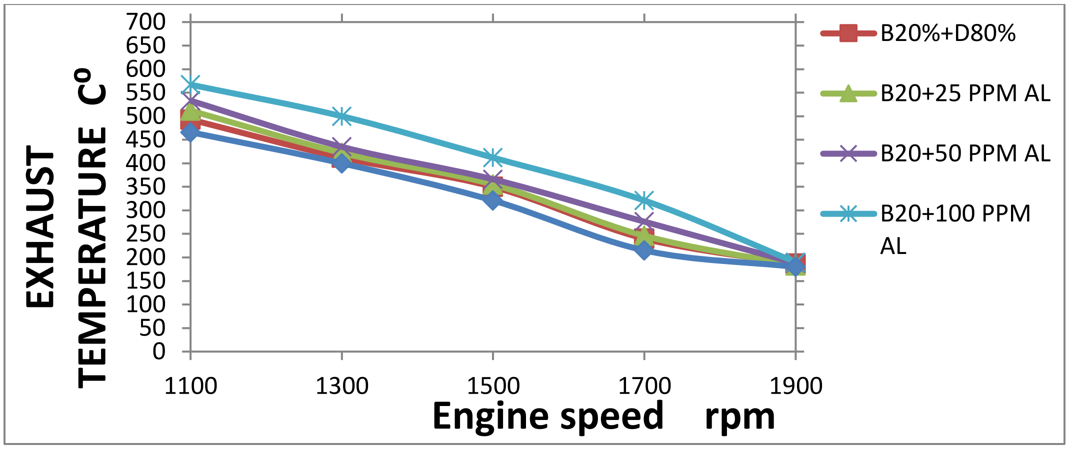

Figure (15): Variation Exhaust Temperature with Engine Speed.

4.2 . Effect of Nanoparticles on Exhaust Emission.

4.2.1 Nitrogen Oxides (NO_X) Emission.

The Figure (16) exhibits the variation of Nitrogen Oxide (NOx) Emission for pure diesel and different ratio of biodiesel blends with the diesel fuel at different engine speed and load. It is observed that the NOx emission deceased with decrease the load and increase the engine speed for all fuels this due to decrease the temperature of combustion chamber [7]. The Nitrogen oxide (NOx) Emission for pure diesel seems to be less than the other ratio of biodiesel blends , and the (NOx) Emission for B20 is found less than the other ratio of biodiesel blends. the (NOx) Emission increased at full load for (B0, B20, B10, B30, B40, and B50) about (1045, 1088, 1133, 1188, 1231, and 1254) ppm respectively at full load 80 kg and low speed engine 1100 rpm.This results are in agreement with [8].

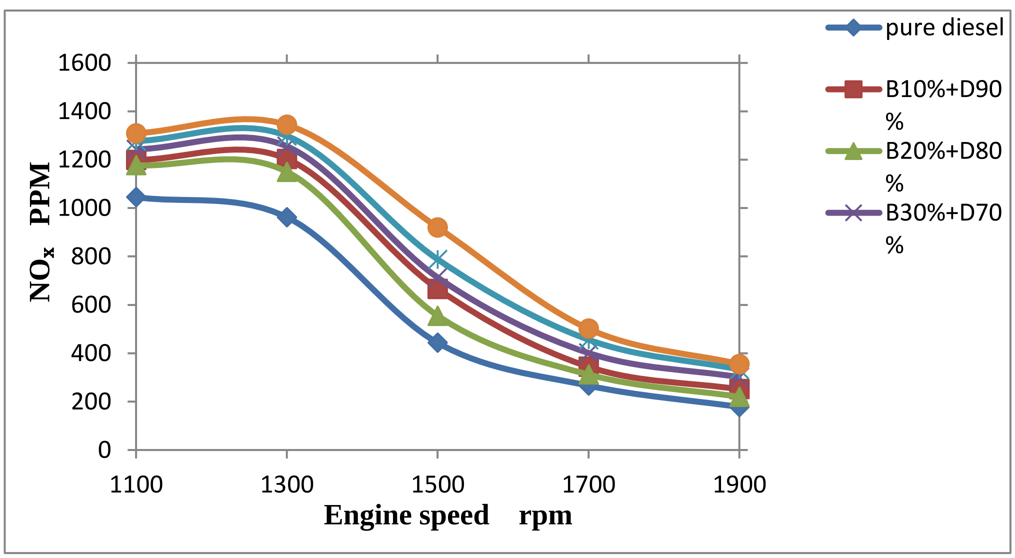

Figure (16): Variation of NO_X Emission with Engine Speed.

4.2.2 The Unburnt Hydrocarbon (UHC) Emission .

The Figure (17) manifests the variation of unburnt hydrocarbons (UBHC) emission with variation the engine speed and the loads. It is seems that the Unburnt hydrocarbons Emissions characteristic for all ratio of biodiesel blends is less than the pure diesel fuel, and the B20 is less than the biodiesel blends and pure diesel fuel. This is because of the B20 have a presence sufficient oxygen to make a complete combustion that leads to decreases the unburnt hydrocarbons (UBHC) emissions[16]. The (UBHC) for B20 at full loads is less than the (B0 , B10 , B30 , B40 , and B50)which is (25.4% , 19.6% , 13.7% , 7.8% and 3.9%) respectively at full load 80 kg and low engine speed 1100 rpm.

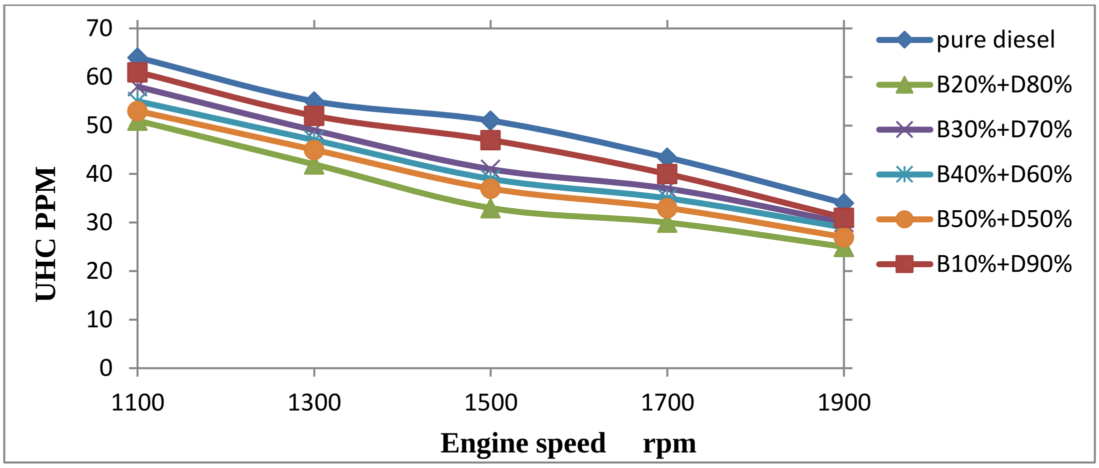

Figure (17) : Variation UHC Emission with Engine Speed.

4.2.3 The Carbon Monoxide (CO) Emission.

The Figure (18) demonstrates the variation of carbon monoxide (CO) with increases the engine speed and decreases the engine loads. The carbon monoxide is a toxic gas product from all hydrocarbons combustion is also decreasing with increasing the oxygen content of the fuel blends . It is observed that the carbon monoxide (CO) emission for all ratio of biodiesel- diesel blends at full load is less than the pure diesel fuel .the (CO) emissions for B20 at full load is lower than the all biodiesel blends, these decreasing indication for more complete combustion of the biodiesel blends[9]. The CO emission for B20 at full load is lower than the fuels(B0, B10 B30, B40, and B50) is by (33%, 26.66%, 24.13%, 12% and 8.334%) respectively at full load and low speed engine 1100 rpm.

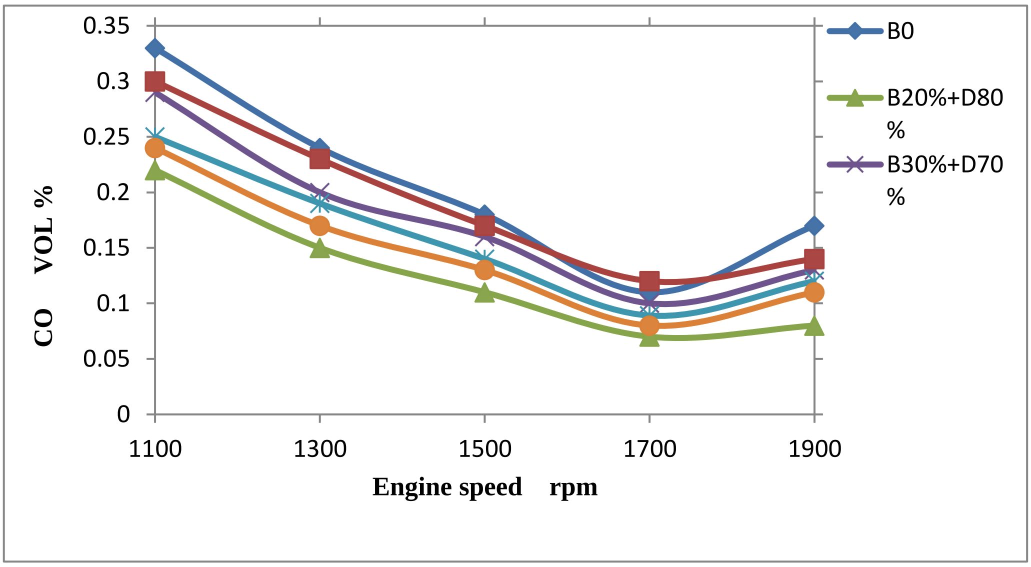

Figure (18) : Variation of CO Emission with Engine Speed.

5. Conclusions.

The diesel engine performed satisfactorily on biodiesel , so that the biodieselcan be used as an alternative fuel in existing diesel engine without any hardware modification . It could be concluded that the 20% percent blend of biodiesel with pure diesel fuel can be observed is the best blend in regard to performance and exhaust emission characteristics as compared to all other blends. Also biodiesel reduces the environmental impacts of generators and transporaion. Reduces the dependence on crude oil Hence the biodiesel fuel may be used as alternative fuel than the petroleum fuels in the compression ignition engine because of its low emission characteristics and equivalent energy.

Conflicts of Interest

The author declares that they have no conflicts of interest.

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الخلاصة

يدرس هذا البحث تأثير إضافة الجسيمات النانوية إلى وقود الديزل الحيوي على خواصه الفيزيائية وأداء المحرك وانبعاثات غازات العادم. محرك الاختبار المستخدم في هذه الدراسة هو محرك ديزل نوع فيات، أربع أسطوانات، أربعة أشواط، تبريد بالماء، حقن مباشر، نسبة الانضغاط 17: 1. الاختبارات اجريت عند تطبيق الحمولة الكاملة على المحرك من خلال مقياس القدرة الديناميكي الهيدروليكي. تم أستخدام نوع واحد من الحبيبات النانويه وبجرع مختلفة 25 ، 50 و100 جزء من المليون وبقطر 25 نانوميتر وتمت التجارب بسرعات وأحمال مختلفة. أن أضافة الحبيبات النانوية حسن من الخواص الفيزيائية للوقود النانوي مثل تحسن الكثافة واللزوجه والعدد السيتاني والقيمه الحراريه. كما أظهرت التجارب تحسن واضح في أداء المحرك حيث أنخفضت نسبة أستهلاك الوقود النوعي بنسبة 15.5% للجرعه 25 و 10.4% للجرعه 50 و6.13% للجرعه 100مقارنة مع نسبة الخلط 20% بدن اضافة الجسيمات النانويه عند أعلى حمل وزيادة الكفاءة الحرارية المكبحية للجرعة 25 بنسبة 20.8% و17.4 للجرعه 50 و4% للجرعه 100 مقارنة مع نسبة الوقود الحيوي 20% بدون أضافة جسيمات نانوية. أما خصائص الانبعاثات فقد قلت بشكل ملحوظ عند أضافة الجسيمات النانوية، حيث أنخفضت نسبة الهايدروكاربونات غير المحترقة وأحادي أوكسيد الكاربون المنبعثة من محرك الديزل عند أستخدام الوقود النانوي بجرعة 25 جزء من المليون بنسبة 15.6% للهايدروكاربونات غير المحترقة و18.18% لأول أوكسيد الكاريون مقارنة مع الوقود الحيوي 20% بدون أضافات نانوية عند الحمل الكامل. وبنسبة أنخفاض 32.8% للهايدروكاربونات غير المحترقة و 45.4% لاول أوكسيد الكاريون مقارنة مع الديزل العادي عند الحمل الكامل. أما انبعاثات أكاسيد النتروجين فقد زادت بنسبة 2.1% للجرعة 25 مقارنة مع الوقود الحيوي 20% بدون جسيمات نانوية وبنسبة 14.9% مقارنة مع الديزل العادي.

الكلمات الدالة: الديزل، وقود الديزل الحيوي، الأداء، خصائص الانبعاث.