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EFFECTS OF ALUMINA NANOPARTICLES ADDITIVES INTO JOJOBA METHYL ESTER-DIESEL MIXTURE ON DIESEL ENGINE PERFORMANCE

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Abstract

Currently, using biofuels to operate diesel engines gets a great attention to the extent that it could replace the limited conventional fossil fuels. These fuels have a closed life cycle (renewable) and they have a remarkable effect on the global greenhouse phenomena. Moreover, the use of non-edible vegetable oils is considered a good choice after a suitable chemical and/or thermal treatment to convert them into esters. The use of jojoba oil shows a promising alternative fuel for conventional diesel fuel even there were unfavorable effects including power reduction. The wide spread usage of nano additives to improve the combustion quality may be a good solution for these problems. This study represents an experimental investigation to examine the effect of nano additives on diesel engine performance at variable operating conditions of load and speed. In this work, alumina nano-particles are added to a mixture of jojoba methyl ester (biodiesel) and conventional diesel fuel at the most recommended value (20% biodiesel and 80% diesel fuel) with different doses from 10 up to 50 mg/l. The received mixture is homogenized with an ultrasonicator mixer. It is found that, the appropriate nano-additives dose corresponding to optimal engine performance is about 30 mg/l. At this dose, the overall BSFC is reduced by about 6%, engine thermal efficiency is increased up to 7%, and all engine emissions have been reduced (NO_x about 70%, CO about 75 %, smoke opacity about 5%, and UHC about 55 %) compared with the corresponding values obtained when only a blended fuel of 20% biodiesel is used.

KEY WORDS

Jojoba Methyl Ester (JME), Alumina nano additives, Diesel engine, Engine performance, Emission

INTRODUCTION

Diesel engines are commonly used for heavy-duty applications; including transportation and power generation sectors due to their fuel economy, reliability and durability compared with gasoline engines. However, diesel engines emit different toxic compounds including particulate matters (PM), nitrogen oxides (NO_x), Unburned Hydrocarbons (UHC) and smoke opacity. Furthermore, the wide applications of the diesel engines increase the consumptions of the fossil fuel. At the same time, the fast depletion of the conventional fossil fuel and the increase of its price make the looking for alternative sources of fuel is urgent objective. In this state, the biofuel is a promising alternative substitute of the conventional diesel fuel, as it is environmental friendly renewable fuel. The liquid form of biofuel is commonly called biodiesel as its properties are similar to those of diesel fuel. Biodiesel can be produced from vegetable oils as well as animal fats. It is always recommended to use non-edible vegetable oils rather than edible oils since edible oils are used for food production while non-edible oils are not suitable for human foods otherwise additional debate about food crises could arise [1], [2], and [3]. The most recommended non-edible oils are those generated from plants that do not need huge amount of water or can grow in the barren lands using waste water [2], [3], [4], and [5]. Among of these plant is the Jojoba plant that can grow in desert and its seed has more than 50% of its weight as oil. Thus jojoba oil would be suitable resource for biodiesel production. The Egyptian jojoba oil (GREEN GOLD) has the advantages of its low price (0.8 €/kg), and its low chemical reactivity [6]. The raw jojoba oil is converted into biodiesel via trans-esterification process to produce Jojoba Methyl Ester (JME). There are many trials to use JME as an alternative fuel for diesel engines due to its superior ignition characteristics [7], [8], and [9]. These studies revealed that, the use of JME leads to a slight loss of engine power and higher soot and NO_x emissions. These problems can partially be reduced by use of blending fuels from JME and diesel fuel. The most recommended JME content within the mixture of JME and diesel fuel is found to be 20% that possesses physical properties approaching the ASTM standard values; this mixture is symbolized as B20 [9], [10].

Currently there is a large interest to use nano-additives to enhance the combustion quality of the burned fuel. Generally, the use of nano-particles in the form of oxides as aluminum oxide (alumina – Al_2O_3) and others in the combustion zone behave as a catalyst [11]. These additives enhance the radiative-mass transfer properties, reduce the ignition delay and enhanced the ignition temperature characteristics of the fuel within the combustion zone [12]. For engine applications, there are many trials to study the effect of nano-additives on engine performance. Accordingly, a number of experimental investigations have been conducted with the use of nano-additives blends with biodiesel and diesel fuel to improve fuel properties and engine performance, as well as to reduce the engine emissions [13],[14],[15,[16],[17], and [18].

Selvan et. al. [13] added cerium oxide nanoparticles (mean size of 32 nm) to diesel and diesel-biodiesel–ethanol mixtures to study the effect of these additives on engine performance. They found that, these additives improve the BSFC and the engine thermal efficiency, increase the peak pressure and a significantly reduce the emission level. The use of cerium oxide nano particles (with size varied from 10 to 20 nm) added to biodiesel leads to the increase of the engine thermal efficiency (up to 1.5%), the reduction of UHC (up to 40%), and the reduction of NO_x emissions (up to 30%) when the dosing level varied from 20 to 80 ppm [14]. The use of 100 mg/l nano particles from Magnalium (Al-Mg) and cobalt oxides (CO_3O_4) (size from 38 to 70 nm) leads to a reduction of diesel engine emissions (UHC by 50%, Carbon monoxide - CO by 50%, and NO_x by 45%) and improving the engine thermal efficiency (about 1%) [15]. The addition of 25 to 50 ppm of alumina nanoparticles (of size 51 nm) on jatropha-biodiesel fuel leads to a significant improving of engine mechanical and emission performance [16]. However, there is no recommended value for the dose of nano additives into the used fuel. It was only mentioned that the use of nano additives beyond 100 mg/l is not recommended as engine performance is worsened [17].

The present work aims to study the effect of alumina nanoparticles added to a mixture of 20% jojoba methyl ester (biodiesel) and 80% by vol. diesel fuel as it is the most recommended value to use blended biodiesel on engine performance.

EXPERIMENTAL SETUP AND PROCEDURE

A single cylinder diesel engine (DEUTZ F1L511) of technical specifications summarized in Table 1 has been employed as the test engine in the present work. A schematic layout of the whole experimental setup equipped with the necessary instruments to measure different engine parameters is shown in Figure 1. DC generator (MEZ-BURNO) of maximum electric power output of 10.5 kW power has been coupled directly to the test engine to determine the engine brake power. The output power of DC generator is consumed by a series of electric heaters within flowing water (the flowing water is used to keep the heater resistance at fixed value during all experiments). In this case, an external controllable excitation electric circuit consisting of an AC autotransformer (Variac) and a rectifier bridge is used to supply the DC generator with the magnetic field.

Table 1: Technical specifications of the test engine

Engine parameters	Specification
Engine model	DUETZ F1L511
Number of cylinder	1
Bore, mm	100
Stroke, mm	105
Displacement, cc	824
Rated power, kW/hp	5.775/7.7
Rated speed, RPM	1500
Idle Speed, RPM	900
Maximum torque, N.m	44/900 RPM
Injection point.	24 ˚ C.A, BTDC
Type of Injection.	Direct injection
Type of cooling.	Air cooling
Starting up	Electrical
Injection pressure	175 bar

The present system provides a facility to measure engine performance at different operating conditions of engine load and engine speed. The load is chosen and defined by selecting the specific values of the generator excitation voltage via autotransformer. The engine rated power of 5.775 kW at 1500 RPM has been selected as a reference point to define the load ratio applied on the engine shaft; and so the corresponding excitation voltage is chosen as the reference value. The engine load ratio is obtained by controlling the excitation voltage to the DC generator relative to the pre-selected reference value; thus the excited voltage is the load ratio multiplied by the excitation voltage supplied at rated load.

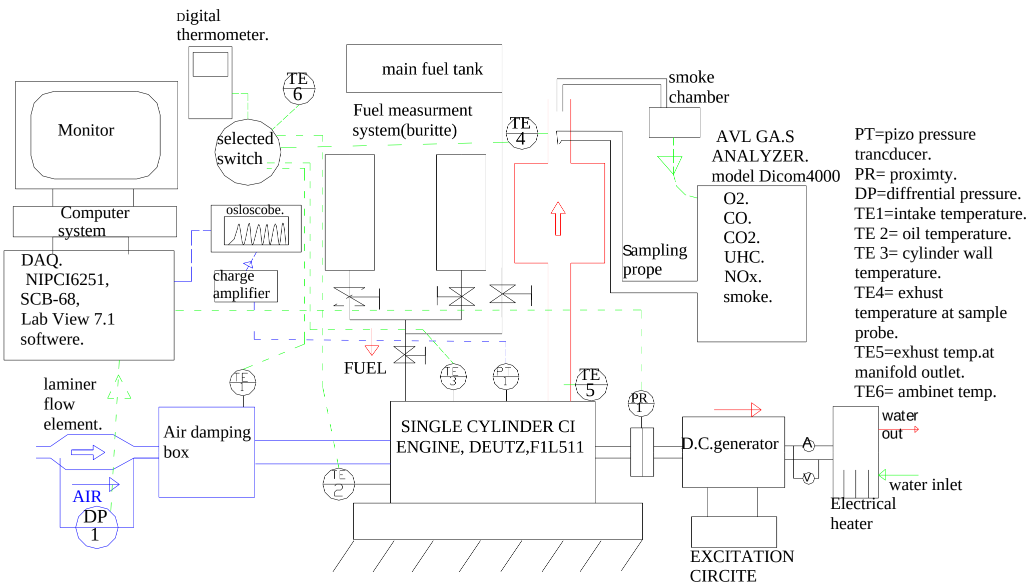

Figure 1: Schematic diagram of the test rig

The engine brake power has been determined by measuring the DC generator output volt and current. The fuel consumption is measured by recording the time needed to consume a specific volume of the test fuel contained within a scaled glass jar. The intake airflow rate is measured by laminar flow element (MERIAM-50MC2) connected to a damping air box of 0.45 m^3. Digital optical tachometer (Pioneered Electrical & Research Corporation, model DS-303) is used to measure the engine speed. Temperature measurements have been carried out at different locations in the experimental set up; including ambient, intake, oil, exhaust, and cylinder wall. For this purpose, five calibrated thermocouple probes of type (K) are installed in these locations. A selecting switch (type omega) is used to switch among these thermocouples and the signals are readout by a digital thermometer (omega-model 650).

The engine emissions are measured by AVL Dicom 4000-NO_x self-calibrated exhaust analyzer (suitable for both Petrol and Diesel Engines). The exhaust gas to be analyzed is sucked by a membrane pump and distributed to the different built-in electrochemical (for O_2 and NO_x) and infrared (IR for CO, CO_2, and UHC) sensing cells; technical specifications are shown in Table 2.

The in-cylinder pressure has been measured by a Kistler piezoelectric pressure sensor (model 6061B) connected with Kistler charge amplifier (model 5018A). The crank-angle encoder of model LM12-3004NA (at detecting distance of 4 mm supplied with DC voltage up to 36 V) has been adjusted to work effectively at the location of the piston top dead center (TDC). The location of TDC has been detected by the help of a digital liner displacement (SONY-MAGNESCALE LY-1115) relative to the position of the proximity. During this process, the injector is removed and the linear displacement sensor is fixed on the piston head. The flywheel is rotated slowly upward until the device reading is inflected (the digital liner displacement has sensitivity of 5 µm) this position is designated as the TDC and the proximity is allowed to sense only this location. This procedure is repeated many times to confirm the proximity reading at TDC.

Table 2: Technical specification of AVL Dicom-4000 NOx Exhaust gas analyzer

Gas emission	Measuring range	Resolution	Uncertainty
Smoke opacity	0---100%	0.1%	0.1%
CO	0---10%by vol.	0.01% by vol.	0.1%
CO2	0---20% by vol.	0.1 % by vol.	0.5%
HC	0---20000 ppm	1 ppm	3%
O2	0---25% by vol.	0.01% by vol.	0.04%
NO_x	0---5000 ppm	1 ppm	0.02%
Engine speed	250---8000 RPM.	10 RPM	0.125%
Oil temperature	0---120 °c	1 °c	±1°c

Both signals from the charge amplifier and the proximity are converted from analog to digital data via Data-Acquisition Card (DAQ model NI PCI-6251 with terminal block SCB-68) that is installed on PC and controlled by LabView software. In the same time, the signals from charge amplifier and encoder are connected to digital storage oscilloscope (Tektronix 2221A, 100 MHZ).

Quantitative evaluations of the expected uncertainty in the present measurements have been carried out following the procedure of Kline [19]. The maximum uncertainty in measurement of brake power, brake specific fuel consumption, and engine speed are found to be 0.9 %, 2.2 % and 0.15 % (± 2 RPM), respectively.

First, the experimental test procedure discussed in the current study starts by warming up the engine using diesel fuel stored in the main tank. Next, the fuel line is switched to use the test fuel. Then, the required engine load percentage is adjusted by regulating the excitation voltage supplied to the generator. After that, the rack position is used to control the required engine speed. Finally, readings from the measuring devices for a particular test are recorded at steady state condition of the engine operation. This procedure is repeated to cover the engine speed range at the specified load percentage; according to the test program summarized in Table 3. At the end of a specified load test, the engine is allowed to run using conventional diesel fuel for half an hour, under no load at 900 RPM to avoid thermal cracking, and make sure that the engine fuel system is cleaned from any residuals of the previously tested fuel.

Table 3: The experimental conditions

Fuel type	Load percentage	Speed
D100, JB20D, JB20D10A JB20D20A, JB20D30A JB20D40A, JB20D50A	0%, 25%, 50%, and 75%	1300 and 1500 RPM

Biodiesel Production

The Non-edible Egyptian jojoba raw oil is used to produce the biodiesel fuel using a laboratory-scale setup. A schematic diagram of the current setup is shown in Figure 2. The setup consists of mechanical stirrer (servo-dyne mixer head with controllable time range up to 100 min and stirring speed up to 6000 RPM), controlled hot plat, three beakers (2000 ml, 500ml and 250 ml), sensitive scale, and thermocouple placing into flask to observe the reaction temperature. The preparation process has been carried out according to the conditions summarized in Table 4. The properties of both base diesel fuel and the received JME are measured according to ASTM standard, as listed in table 5.

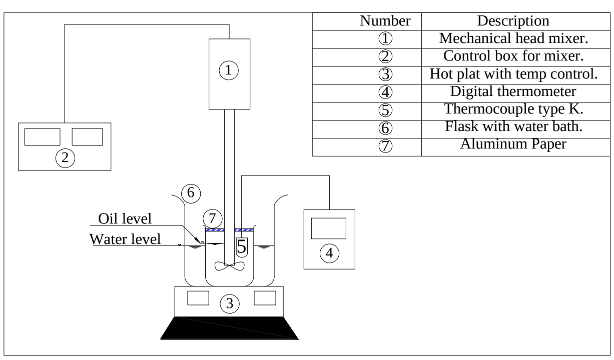

Figure 2: Schematic diagram of JME preparation setup

Table 4: Biodiesel preparation conditions via trans-esterification process

Catalyst and concentration	Methanol: oil Molar ratio	Reaction time, h	Reaction temperature ˚C	Mixing intensity, RPM	Washing times
KOH,0.5wt%	6:1	2	60±1	600	4-5

Table 5: Properties of JME and diesel oil fuel

Property	Test Method	Diesel	JME
Calorific value, kJ/kg	ASTM D-240	45448	44866
Viscosity @40 °C, cSt.	ASTM D-445	3.34	11.72
Density @ 15.56°C ,g/cm^3	ASTM D-1298	0.8427	0.8645
Molecular weight, Kg/Kmol.		191.02	350.73
C,%		86.21	76.01
H,%		11.59	10.05
N,%		1.91	Nil
S,%		0.29	0.3
O_2,%		Nil	13.64

Dispersion of Alumina Nano Particles (AL_2O_3)

The nanoparticles are dispersed into a mixture of jojoba biodiesel-diesel fuel at the recommended composition (20 % by vol. of JME and 80 % of diesel fuel) with the aid of an ultrasonicator (Hielscher UP200S40) at a frequency of 24 kHz for 30 minutes. The ultrasonication technique is the best-suited method to disperse the nanoparticles in a base fluid to prevent the agglomeration of nanoparticles using pulsating frequencies to disperse nanometer ranges into the fluid [16]. The alumina nanoparticles of average size of 20 to 50 nm are supplied by Nanotech Egypt Company, with detailed specifications list in Table 6. The manufacturer measures the morphology of alumina nanoparticle as shown in Figure 3. The nanoparticles are weighted according to the predefined mass fraction in the range of 10 to 50 mg/l with step of 10 mg. Correspondingly the received mixture is symbolized as JB20D 10A, JB20D 20A, JB20D 30A, JB20D 40A, and JB20D 50A indicating nano contents of 10, 20, 30, 40, and 50 mg/l in JME-diesel mixture, respectively. A sample of JB20D containing 50 mg/l alumina nanoparticles has been allowed in a long tube under static conditions to observe mixture stability. There was no mixture separation observed for two weeks.

Table 6: Details of alumina nanoparticles

Item	Specification
Manufacturer	Nanotech company, Egypt
Chemical name	Gamma Aluminum Oxide (Alumina, Al_2O_3) Nano powder, gamma phase, 99.9%
Average particle size	20-50 nm
BET surface area (SSA)	>150 m2/g
Appearance	White
melting point	2045 ºC
boiling point	2980 ºC
density	3.9 g/cm3

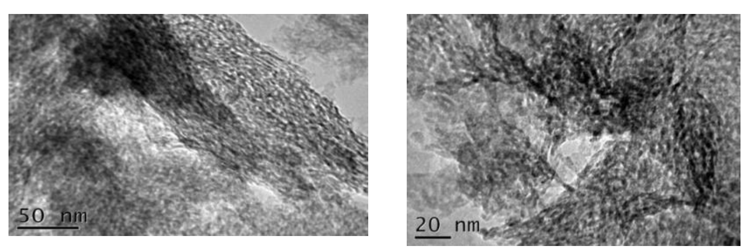

Figure 3: Transmission Electron Microscopy image of alumina

RESULTS AND DISCUSSIONS

The mechanical performance and the emission characteristics of diesel engine using different fuels; including diesel and jojoba biodiesel-diesel fuel containing 20% by vol. as JME (JB20D) with and without nano particle additives according to test program in Table 3 have been determined. Based on the combustion data, cylinder pressure is plotted against crank angle. The performance parameters, such as brake thermal efficiency and brake specific fuel consumption and the emission concentrations of NO_x, CO, UHC and smoke opacity are plotted against engine load.

Combustion characteristics

The variation of in-cylinder pressure as a function of the crank angle during the end of compression stroke and throughout the initial part of the expansion stroke is recorded for the studied fuels as shown in Figures 4. Any change in the fuel combustion process will affect the trends of the recorded pressure data influencing the value of the peak pressure and its location relative to the crank angle. These major factors are collected for all runs to get a real indication about how fast the heat liberation rate is finished against the upward piston motion (Table 7). At lower engine speed, the in-cylinder aerodynamics is worsened and it is necessary to inject a relatively higher fuel volume to compensate the poor mixing effect between fuel and air. Thus, the peak pressure may be increased while its location is retarded. For conventional fuel (D100), the peak pressure at 75% of the full load and 1500 RPM is found to be 5.7 MPa and it is obtained at 6 º C.A. after TDC (ATDC), while at 1300 RPM they are 5.9 MPa and 7.5 º C.A. ATDC, respectively. When the recommended biodiesel-diesel fuel (JB20D) is used a lower value is obtained and its location is retarded. The slight reduction of the peak pressure is due to slight reduction of the heating value of JB20D versus that of D100. While the late to receive this peak value can be owing to the increase in the ignition delay period due to the mixture viscosity and boiling point that worsen the processes of fuel atomization and evaporation. Due to the positive influence of nano-additives on the heat transfer rate during fuel atomization and evaporation, the starting of the in-cylinder combustion process is remarkably advanced. Moreover, the catalytic behavior of the alumina nano-particles improves the reaction rate, so the heat is liberated during shorter duration against the up-warding piston, and higher values of the peak pressures are observed (see Figure 4 and Table 7). The level of nano additives on the in-cylinder combustion process depends on their contents, engine speed, and the load percentage. The data is represented for the most used power of diesel engines; 75 % of the full load at rated engine speed (1500 RPM) and the speed at which the engine volumetric efficiency is maximum (1300 RPM). At this load fraction and speed of 1500 RPM, the lower combustion duration is obtained at nano additive of 20 mg/l, while the peak pressure is obtained at 40 mg/l. However, at 75% of the load and speed of 1300 RPM, the lower combustion duration is obtained at nano additives of 50 mg/l and the peak pressure is obtained at 30 mg/l.

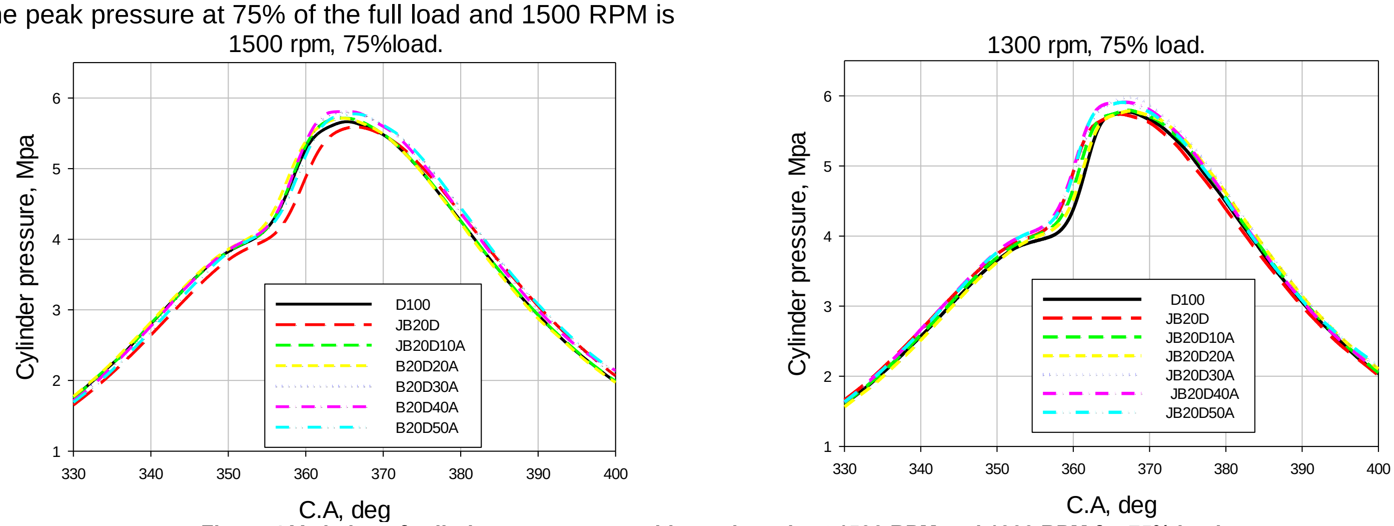

Figure 4 Variation of cylinder gas pressure with crank angle at 1500 RPM and 1300 RPM for 75% load

Table 7:The maximum pressure and its position for different tested fuels at 75% load for 1500 and 1300 RPM

1500 RPM							
	D100	JB20D	JB20D10A	JB20D20A	JB20D30A	JB20D40A	JB20D50A
Peak pressure (MPa)	5.7066	5.6136	5.7256	5.7539	5.8201	5.8355	5.8009
Position ATDC, C.A,deg	6	7.5	6.5	5.5	7.5	7	8.5
1300 RPM							
Peak pressure (MPa)	5.8654	5.7006	5.8648	5.8553	5.9998	5.9411	5.9834
Position ATDC, C.A,deg	7.5	9.5	7.5	7.5	8.5	7	6.5

As it is shown in Figure 4 and Table 7, the addition of nano additives to biodiesel-diesel mixture reduces the ignition delay period and improves the in-cylinder combustion characteristics, therefore leading to the increase of peak pressure values and the reduction of the combustion duration. This effect is increased when the dose fraction increases up to a specific content at which the radiative losses from these particles to the cylinder wall become significant [12]. At higher contents these radiation losses will reduce the in-cylinder temperature consequently the peak pressure will be reduced too. That is why the exhaust gas temperature is reduced as the nano additive concentration is increased no matter the engine speed, as shown in Figure 5.

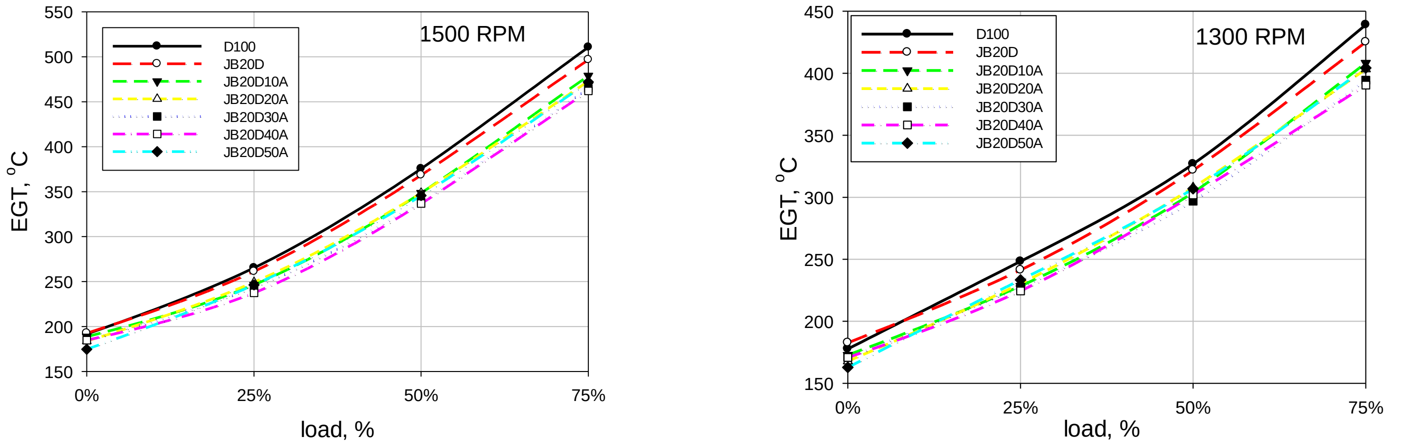

Figure 5: Variation of EGT with load percentage at 1500 RPM and 1300 RPM

Performance characteristics

The engine performance is described in terms of fuel economy factors as the Brake Specific Fuel Consumption (BSFC) and/or the engine thermal efficiency. The BSCF is defined as the engine fuel consumption to produce a unit of power; in SI units as g/kW.h, while the engine thermal efficiency is ratio of the output power to the supplied chemical energy throughout the fuel. From the analysis of the experimental data at engine speed of 1500 and 1300 RPM for different engine loads, Figure 6 is obtained. It can be noted that, the use of biodiesel-diesel mixture leads to a slightly decrease in the engine thermal efficiency and so an increase in BSCF. The effect of nano additives on the variation of engine thermal efficiency and the BSCF at specific engine speed at various engine loads are also represented in Figure 6. It is observed that, the engine thermal efficiency is increased with nano-additives approaching values obtained when pure diesel fuel is used. This may be owing to the better quality of the in-cylinder combustion process as stated above. Another factor related to better combustion is probably attributed to the higher surface-area-to-volume ratio which in turn allows more amount of fuel to react with the air leading to enhancement in the brake thermal efficiency [16]. These effects will allow better usage of the chemical energy that is way thermal efficiency is increased or the BSFC is reduced (the maximum observed reduction is about 6 %).

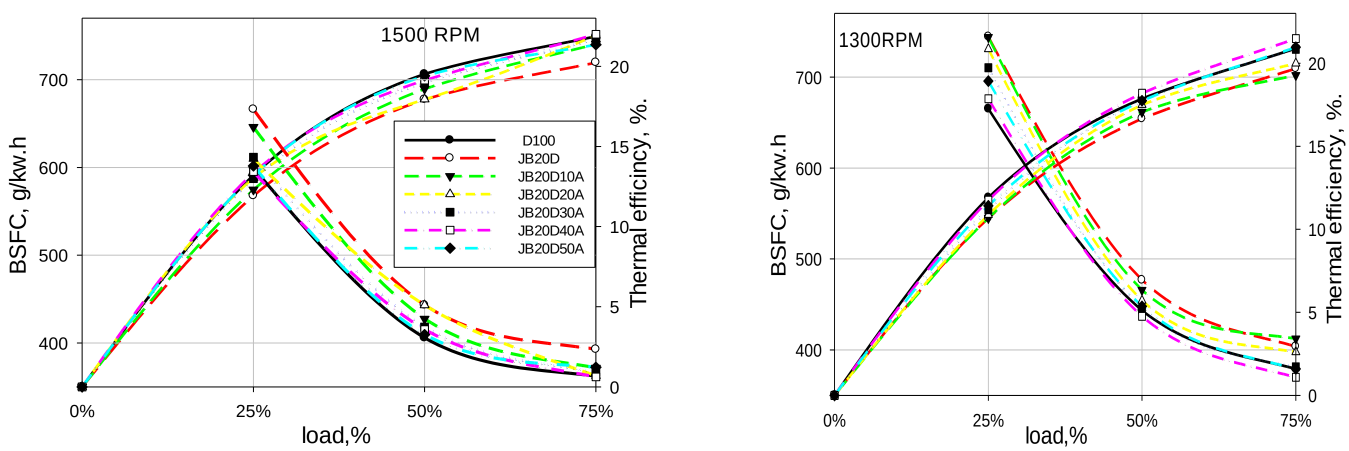

Figure 6: The variation of the engine thermal efficiency and the brake specific fuel consumption with load at 1500 RPM and 1300 RPM

Engine Emission characteristics

The variation of the engine emission characteristics such as NO_x, UHC, CO and smoke opacity are obtained at different engine loads and speeds using the tested fuels as shown in Figures 7 throughout Figure 9. It can be clearly noticed in figure 7 that no matter the engine speed or engine load is, jojoba biodiesel-diesel fuel leads to a slightly increase in the values of NO_x emissions. This effect can be attributed to the positive effect of oxygen contents of JME that lead to the formation of active radicals as OH. These radicals will proceed the reaction rate for the formation of different species, including NO_x that will be frozen when it leaves the reaction zone. The energy content of oxygenated fuels as biodiesel is lower than that of fossil fuels (for JME this is only 1.3 %); this difference in the heating value would be dominant at higher biodiesel contents. For the current biodiesel content (20%) the positive effect of oxygen contents on the chemical reaction will be dominant, thus the final level of NO_x emissions is increased. The catalytic behavior of nano particles will proceed the reactions to be completed forming the final products (heterogeneously combustion) with the least thermal break down of the hydrocarbon compounds. That way, the existence of lower active radicals lowers the possibility to form thermal NO_x. This behavior of nano-particles within the combustion zone is coincided with the NOx emissions out of the engine. However, there are slight differences in NO_x emissions at different nano fractions; this may be owing to the level of the combustion quality indicated by the peak pressure value. Correspondingly, the maximum reduction in the NO_x emissions is obtained at nano-additive of 20 mg/l for both tested engine speeds.

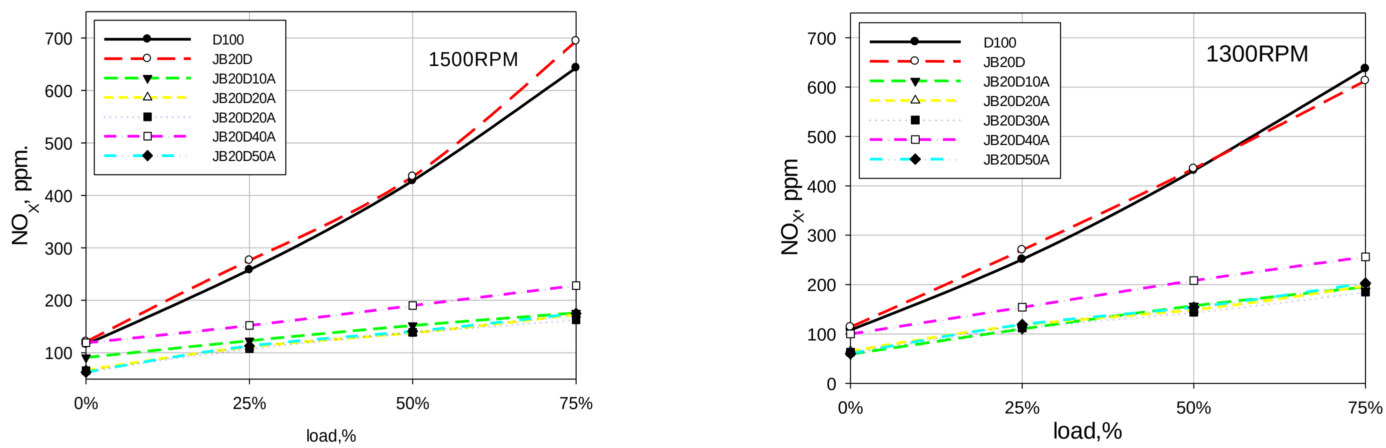

Figure 7: The variation of NO_x emissions with engine load % at 1500 RPM and 1300 RPM

Due to the high viscosity of the blended biodiesel-diesel fuel, the smoke opacity level is increased. As well as, due to alumina nanoparticles, the magnitude of the smoke opacity is lower compared to that of jojoba biodiesel-diesel fuel as shown in the Figure 8. The reduced smoke opacity in the case of alumina nanoparticles blended jojoba biodiesel-diesel fuels is caused by the shortening of the ignition delay, the increase of the evaporation rate, and the improved ignition characteristics due to existence of nanoparticles [20]. Kao et al. [21] and Sadhik et.al. [16] have also found similar trends of smoke reduction using aluminum nanofluids blended with the biodiesel fuel.

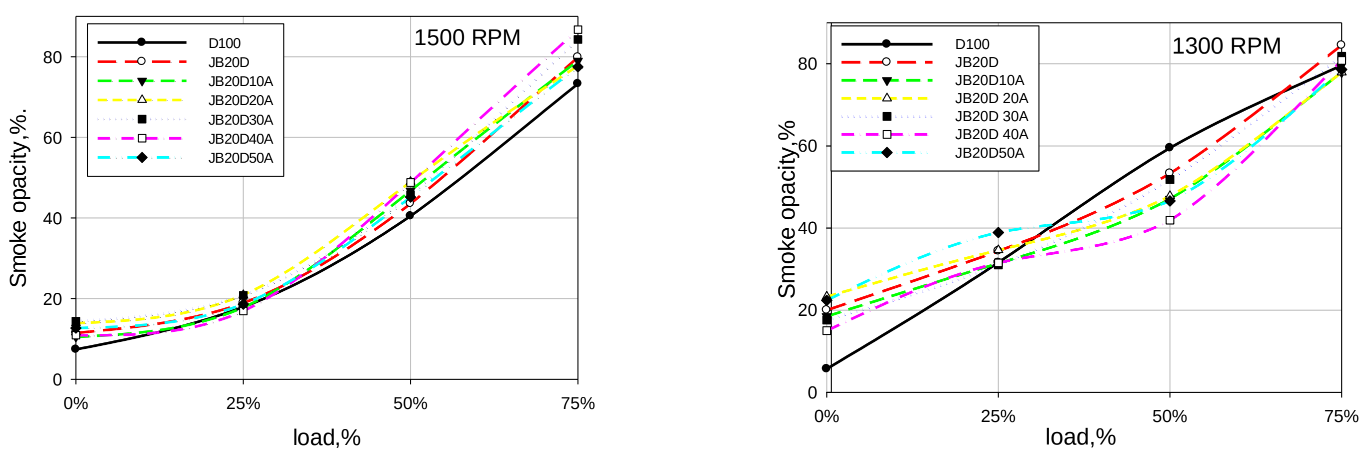

Figure 8: The variation of smoke opacity with engine load % at 1500 RPM and 1300 RPM

As the emissions of CO and UHC have similar formation conditions, they have similar trends as being a function of engine speed and fuel type. The use of biodiesel blend leads to a remarkable increase in both CO and UHC compared with conventional diesel fuel (see Figure 9). This is due to the poor atomization characteristics of high viscous fuels. The nano-additives have a remarkable positive effect on CO and UHC emissions as a result of the catalytic behavior of these nano oxides, in addition to the improved ignition characteristics of alumina nanoparticles and the shortening of the ignition delay [20].

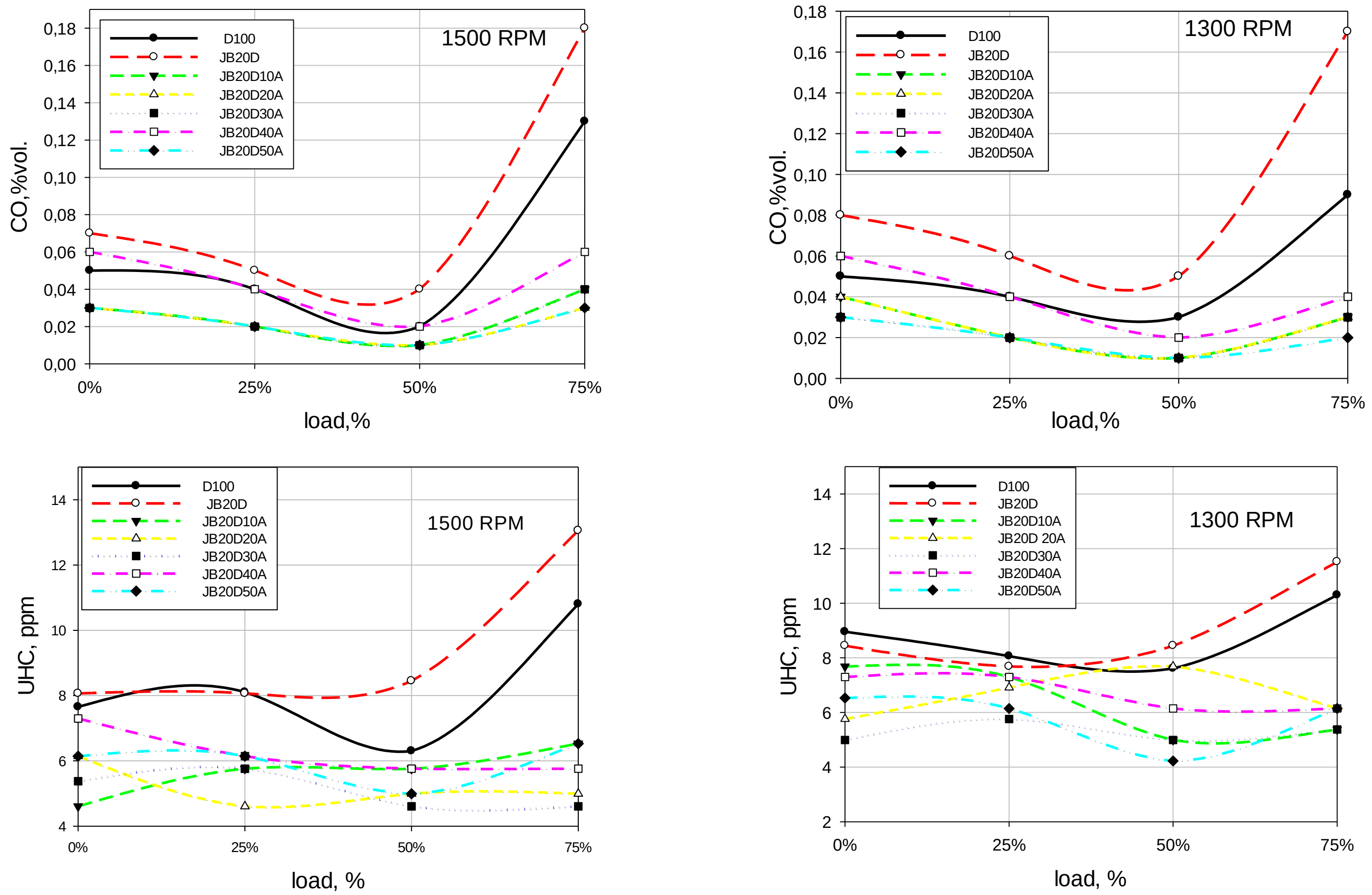

Figure 9: Variation UHC and CO emissions with engine load % at 1500 RPM and 1300 RPM

The summary of results (shown in figure 10) indicates the effect of nanoparticles compared with that of biodiesel-diesel fuel on engine performance. It can be noted that at engine speed of 1500 RPM and engine load of 75% of full load, the maximum increase in the engine thermal efficiency (up to 9 %) and maximum reduction in BSFC (about 8 %) are received at nano-additive level of 40 mg/l, the same behavior at 1300 rpm is also obtained at 40 mg/l. Furthermore, the maximum emission reduction observed for the engine speed 1300 RPM and 1500 RPM at 75 % of the full load are obtained at 20 mg/l dosing level. By comparing the overall effect of nano-additives, it can be concluded that dose level of 30 mg/l will give simultaneously the best overall mechanical engine performance and the engine emission characteristics. This value of dose means lower possibility for mixture separation and lower quantity of unknown long-run effect of the nano-additives on the engine different parts.

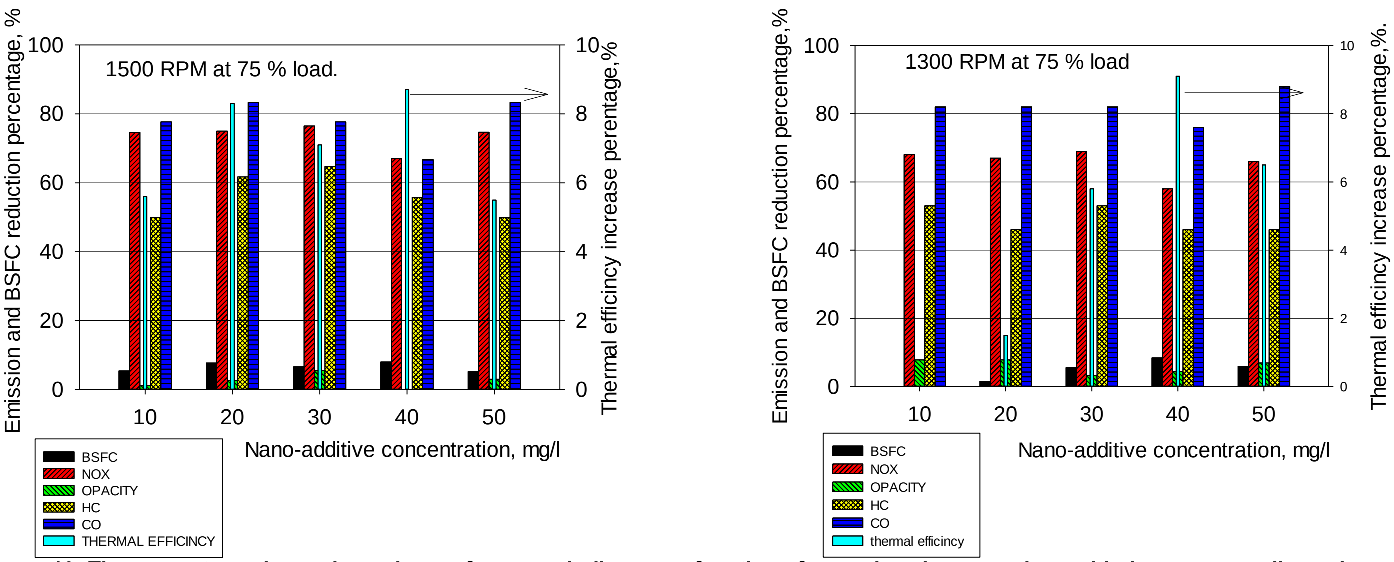

Figure 10: The percentage change in engine performance indices as a function of nano dose in comparison with the corresponding values when biodiesel-diesel fuel is used; decrease of BSFC and NO_x, HC, CO and smoke opacity emissions and increase of engine thermal efficiency

COCLUSION

To conclude, The performance and emission characteristics of diesel engine depends on jojoba biodiesel-diesel fuel mixture (with/without addition of alumina nanoparticles) are investigated at the most important engine speeds (where the rated power and the maximum volumetric efficiency are received) at various engine loads. The major conclusions of this investigation include:

- The peak pressures when conventional fuel is used at 1300 RPM (5.94 MPa) and 1500 RPM (5.84 MPa) are higher than the corresponding values when mixture of 20 % by vol. of JME with 80 % diesel fuel is used.
- The use of nano-additives of alumina not only improves the mechanical performance of diesel engine, but also reduces the emission level of all pollutants (NO_x, UHC and CO and smoke opacity) in the exhaust gaseous due to its catalytic effect on the fuel combustion process, especially in comparison with the effect of biodiesel-diesel mixture.
- A low dose of alumina nanoparticles in the range of 30 mg/l will be recommended to achieve the best engine performance with optimal emission characteristics, particularly to remove the disadvantages related to use of biodiesel blends into diesel fuel (increase of NO_x, UHC, CO and smoke opacity level).

Nomenclature

ASTM- American Society for Testing and Materials
CA - Crank Angle, degree
CO - Carbon Monoxide, %Vol.
EGT - Exhaust Gas Temperature, °C
UHC – Unburned Hydrocarbons, ppm
NO_x - Nitrogen Oxides, ppm
JME- Jojoba methyl ester
D100- Based Diesel fuel
JB20D – 20% jojoba methyl ester and 80% diesel fuel
JB20D10A - 20% jojoba methyl ester and 80% diesel fuel + 10 mg of alumina
JB20D20A - 20% jojoba methyl ester and 80% diesel fuel + 20 mg of alumina
JB20D30A - 20% jojoba methyl ester and 80% diesel fuel + 30 mg of alumina
JB20D40A - 20% jojoba methyl ester and 80% diesel fuel + 40 mg of alumina
JB20D50A - 20% jojoba methyl ester and 80% diesel fuel + 50 mg of alumina

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