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

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Abstract

Currently the use of biofuels to operate diesel engines gets a great attention to replace the limited conventional fossil fuels. Moreover, these fuels have a closed life cycle (renewable) and they have a remarkable effect on the global greenhouse phenomena. The use of non-edible vegetable oils is a good choice after a suitable chemical and/or thermal treatment converting them into esters. The use of jojoba oil showed a promising alternative fuel for conventional diesel fuel even there were unfavorable effects such as the slightly power reduction. The wide spread usage of nano additives to improve the combustion quality of low calorific fuels may be a good solution for the previous problem. In this work, an experimental investigation is carried out to study the effect of nano additives on diesel engine performance at variable operating conditions of load and speed. In this study alumina nano-particles are mixed with a mixture of jojoba methyl ester (biodiesel) and conventional diesel fuel at the most recommended value (20% biodiesel and 80% diesel fuel) and at various fractions from 10 to and 50 mg/l. The received mixture is homogenized with an ultrasonicator mixer.
From this work, the recommended nano-additives dose to receive the optimal engine is nearly 30 mg/l. At this dose level, 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, Emissions

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 fossil fuel. At the same time, the fast depletion of the fossil fuel and the increase of its price make the looking for alternative source of energy 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 more approach those of diesel fuel. Biodiesel can be produced from vegetable oils as well as animal fats. It will be recommended to use non-edible vegetable oils rather than edible oils (edible oils are used for food production while non-edible oils are not suitable for human foods) or additional debate about food crises will be arrived [1], [2], and [3]. The most recommended non-edible oils are those generated from plants that does 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 and so jojoba oil would be suitable for biodiesel production. Moreover, the choice of the Egyptian jojoba oil (GREEN GOLD) is due to its availability in Egypt, 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 receive 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 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 the fuel properties and the 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) into diesel and diesel-biodiesel–ethanol mixtures to study the effect of these additives on the emissions characteristics of the diesel engines. They found that, these additives improve both 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]. In the previous studies, the biodiesel from Jojopa oil with nano-additives is not studies. Moreover, there is no recommended value for the dose of nano additives into the used fuel; except it was mentioned that the use of nano additives beyond 100 mg/l is not recommended as the 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 direct injection diesel engine (DEUTZ F1L511) of technical specifications summarized in Table 1 has been employed as the test engine in the present work. The whole experimental layout equipped with the necessary instruments to measure the 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 the engine performance at different operating conditions of engine load and engine speed. The load values are chosen and defined by selecting the generator excitation voltage values using the autotransformer. The value of diesel 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. The engine load ratio is obtained by controlling the excitation voltage to DC generator such that the excited voltage will be the same ratio from the excitation voltage supplied at the rated engine conditions.

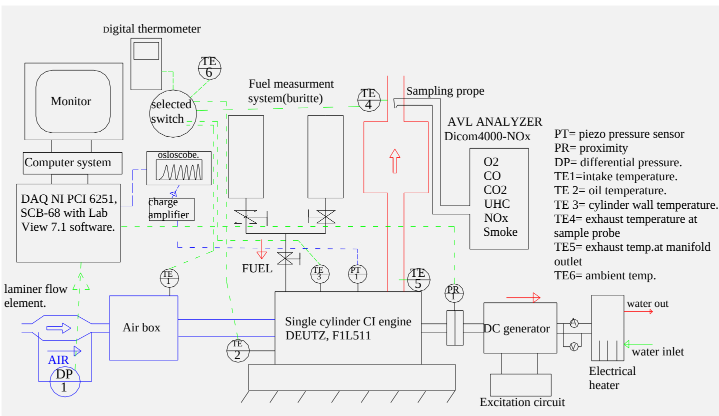

Figure 1: Schematic diagram of the test rig

The engine brake power has been determined by measuring volte and current out from the DC generator. The fuel consumption is measured by recording the time needed to consume a specific volume of the test fuel contained into a graduated glass jar. The intake airflow rate is measured as the flow throughout laminar flow element (MERIAM-50MC2) entering 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 the temperature of ambient air, intake air, oil, exhaust, and cylinder wall. For this purpose, five calibrated thermocouple props of type (K) are installed in these locations. A selecting switch (type omega) is used to switch between these thermocouples and any reading is readout by a digital thermometer (omega-model 650).

The emission is 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 of pressure range up to 250 bar and sensitivity ≈ -25 pc/bar) 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 piston top dead center (TDC). The location of TDC relative to the position of the proximity has been detected by the help of a digital liner displacement (SONY-MAGNESCALE LY-1115). 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 sensitive 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 charge amplifier and the proximity are converted from analog to digital data via Data-Acquisition Card (DAQ model NI PCI-6251with terminal block SCB-68) installed on PC controlled by LabView software. For more justification, 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.

The experimental test procedure adopted in the present work starts by warming up the engine using diesel fuel stored in the main tank. Then the fuel line is switched to use the test fuel. The required engine load percentage is adjusted by regulating the excitation voltage supplied to the generator. The rack position is used to control the required engine speed. The different 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 gas oil 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.

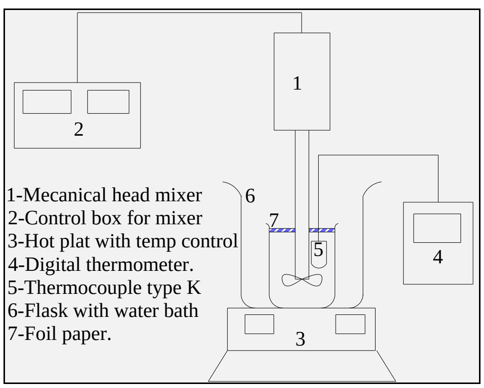

Figure 2: Schematic diagram of JME preparation setup

Table 4: Optimum condition of 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 Particle (AL_2O_3) With Biodiesel-diesel mixture

The nanoparticles is 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 ultrasonic UP200S40) set 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 is supplied by Nanotech Company, Egypt with detailed specifications list in Table 6. Manufacturer determines 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 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 along tube under static conditions to observe mixture stability. During period of two weeks, it is not observed any mixture separation.

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

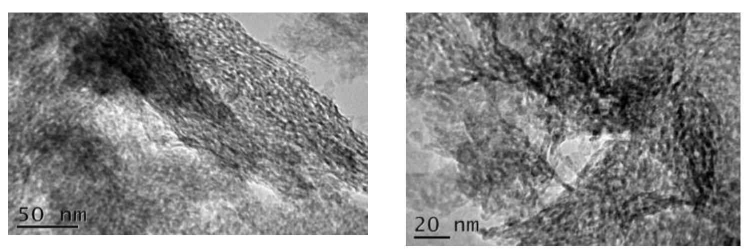

Figure 3: Transmission Electron Microscopy (TEM) image of alumina

RESULTS AND DISCUSSIONS

Mechanical performance and 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 the engine load percentage.

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 recoded for the studied fuels as shown in Figures 4. Before TDC by 24 º C.A. the fuel injection starts, during a sufficient ignition delay period a part of the injected fuel is atomized, vaporized, and diffuse into the in cylinder air forming a cloud of premixed combustible mixture. As the temperature within the engine cylinder exceeds the mixture auto-ignition temperature, the mixture is spontaneously ignited and a fast rise in the in-cylinder is observed. The major part of the injected fuel is then burned via a diffusion mechanism until the burning process is terminated and injected fuel is burned. Any change in the fuel combustion process can be observed from the recorded pressure data. In this case it is important to observe the peak pressure and its location relative to the crank angle. These factors are collected to 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 necessary to balance the effect of the high values of 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 heat reaction rate and so the heat is liberated during shorter duration against the up-warding piston, and so 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 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.

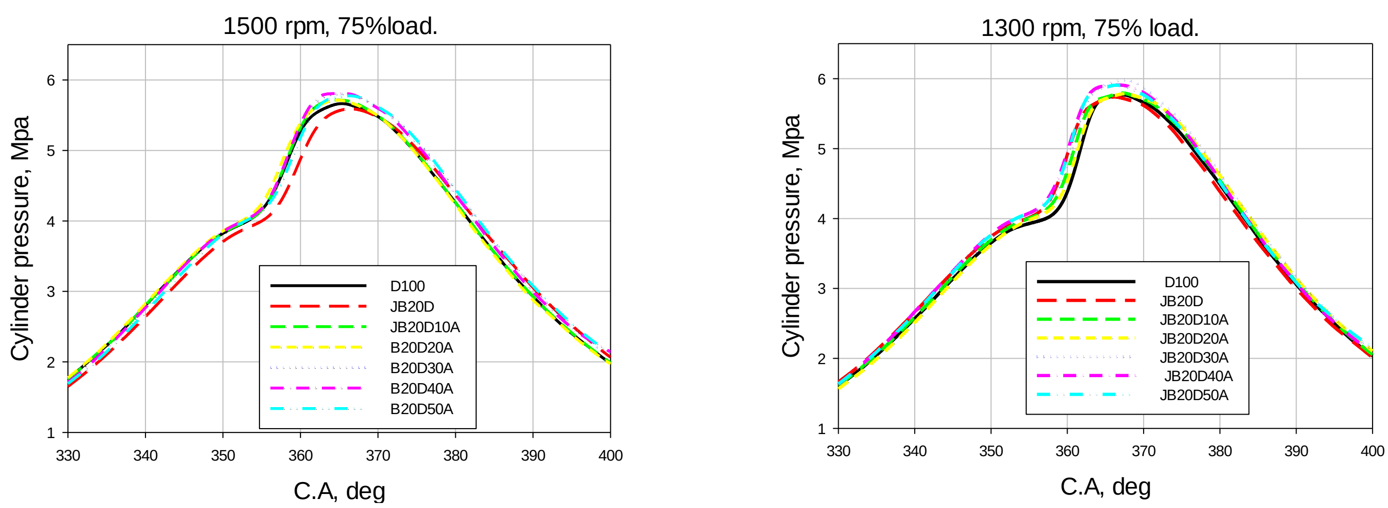

Figure 4 Variation of cylinder gas pressure with crank angle at 1500 RPM and 1300 RPM for 75% load

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

From Figure 4 and Table 7 it can be concluded that the addition of nano additives to biodiesel-diesel mixture reduces the ignition delay period and improves the in-cylinder combustion characteristics, and so leading to the increase of peak pressure values and the reduction of the combustion duration. This effect is increased as the dose fraction is increased up to a specific content at which the radiative losses from these particles to the cylinder wall become significant. At higher contents these radiation losses will reduce the in-cylinder temperature and so the peak pressure will be reduced, this 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.

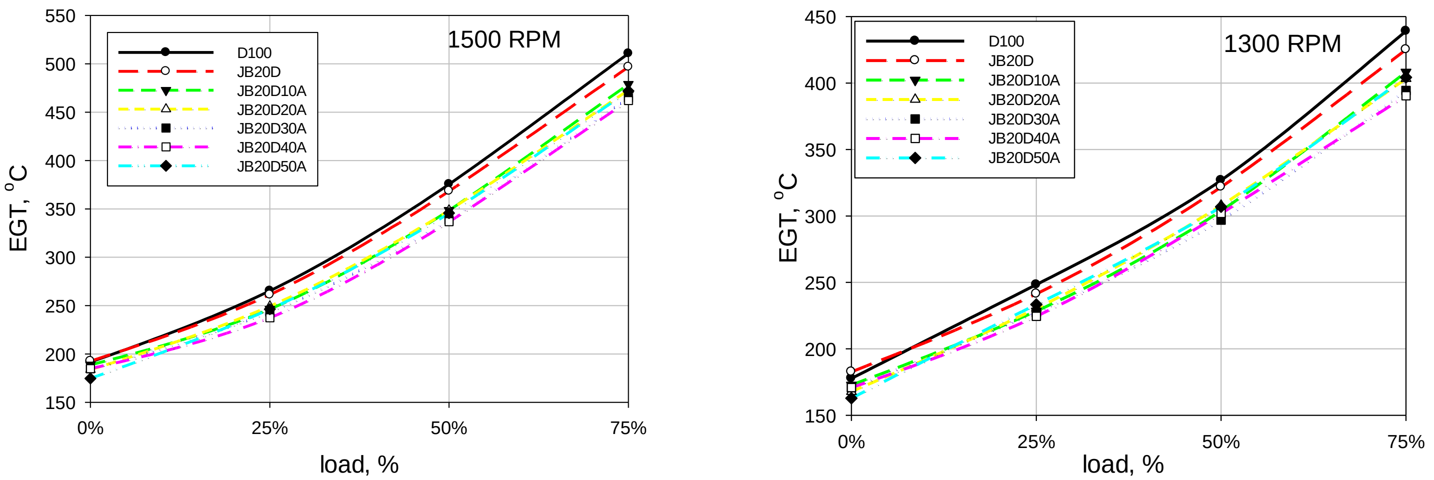

Figure 5: Variation of EGT with load percentage at 1500 RPM and 1300 RPM

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 increase with nano-additives owing to 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 and so thermal efficiency is increased or the BSFC is reduced (the maximum observed reduction is about 6 %).

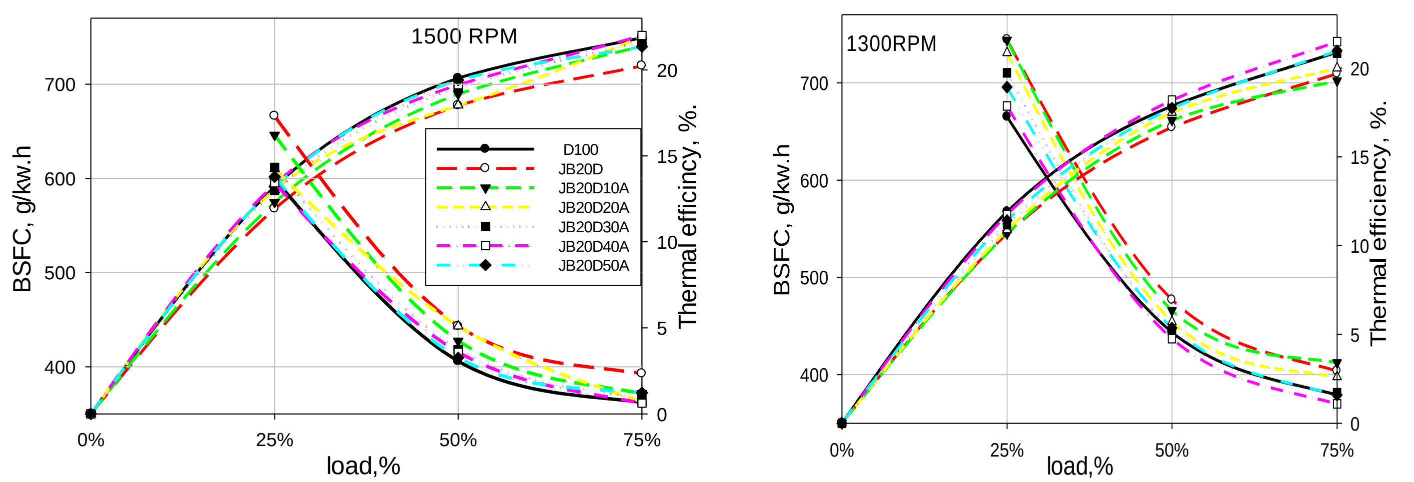

Figure 6: The variation of the engine thermal efficiency and the brake specific fuel consumption with load at 1500 RPM and 1300 RPM

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.

From Figure 7, it can be noted that no matter the engine speed or engine load, jojoba biodiesel-diesel fuel leads to a slightly increase in the values of NO_x emissions. This behavior may be owing to the positive effect of oxygen contents that lead to the formation of active radicals as OH. These radicals will proceed the reaction rate for the formation of different species, among of them NO_x that will be freeze when exit the reaction zone. The energy contents of oxygenated fuels as biodiesel is lower that of fossil diesel fuel (for JME only by 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 and so 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 minimum thermal break down of the hydrocarbon compounds, and so existence of lower active radicals lowering 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 speed engines.

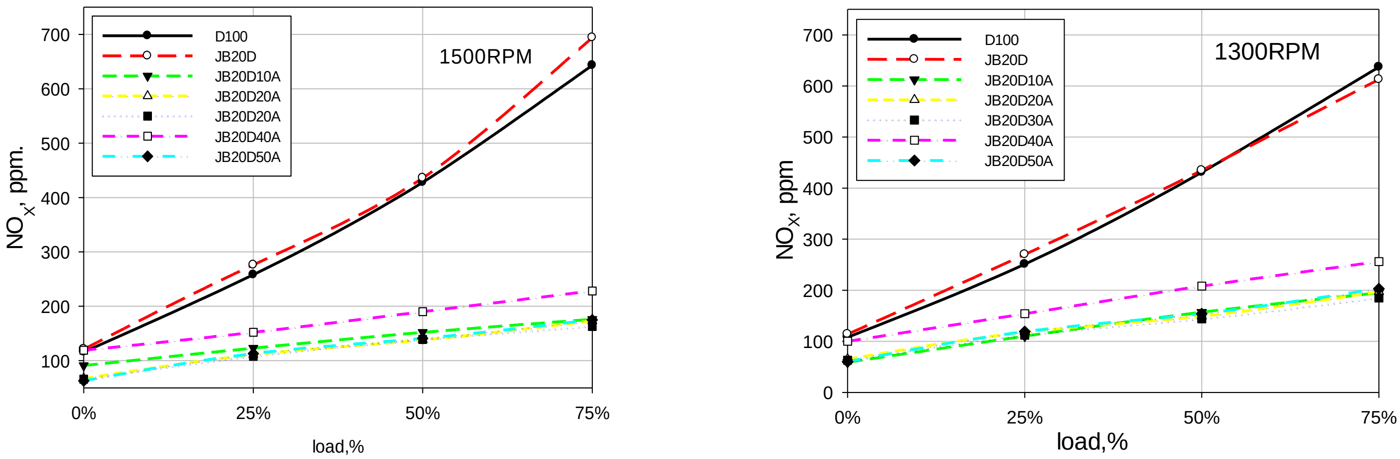

Figure 7: The variation of NO_x emissions with engine load % at 1500 RPM and 1300 RPM

Due to the high viscosity of the blended biodiesel-diesel fuel, the smoke opacity level is increased. The magnitude of the smoke opacity due to alumina nanoparticles 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 due to the shortened of the ignition delay, the increase of the evaporation rate, and the improved ignition characteristics of nanoparticles [20]. Kao et al. [21] and Sadhik with Anand [16] have also found similar trends of smoke reduction using aluminium nanofluids blended with the biodiesel fuel.

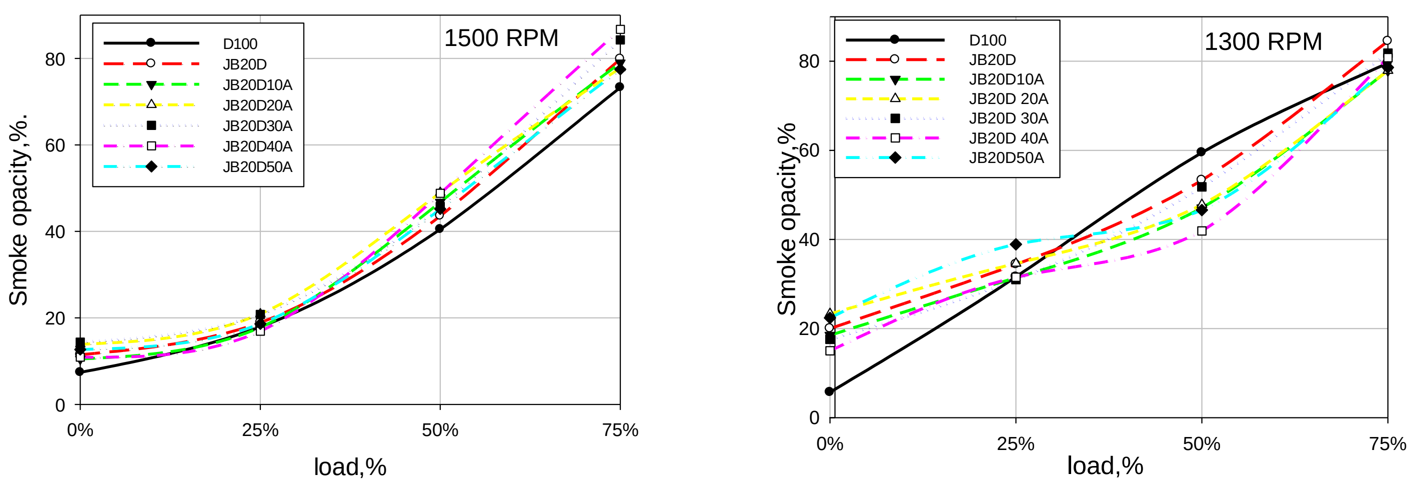

Figure 8: The variation of smoke opacity with engine load % at 1500 RPM and 1300 RPM

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

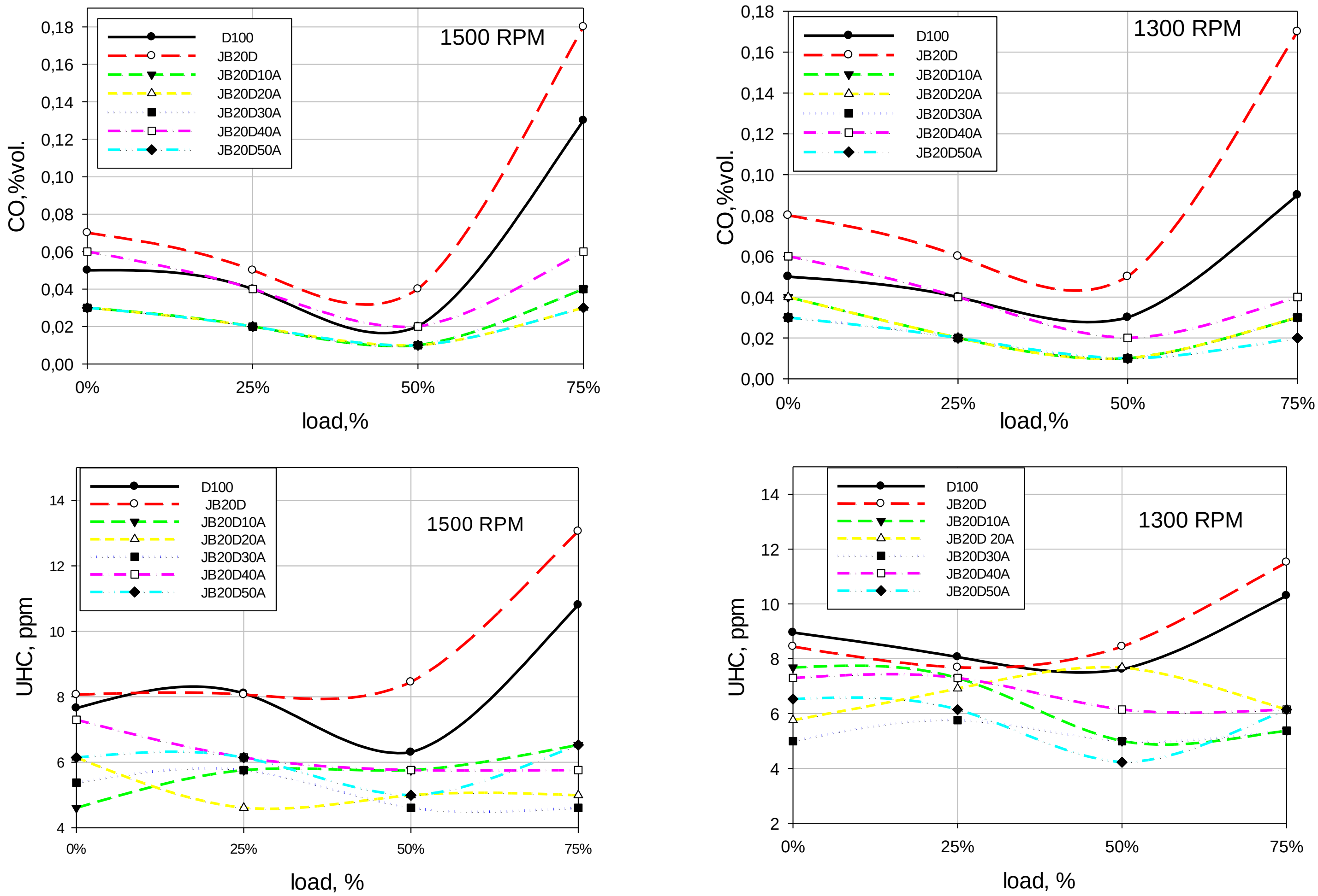

Figure 9: Variation UHC and CO emissions with engine load % at 1500 RPM and 1300 RPM

The summary of results showing the effect of nanoparticles compared with that of biodiesel-diesel fuel on engine performance are collected in Figure 10. 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 obtained also 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. To maintain the mixture stability of dispersed mixture and to reduce the cost of nano-particles, the recommended dose should be the minimum that would give the best significant improving effect. In accordance to that and 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.

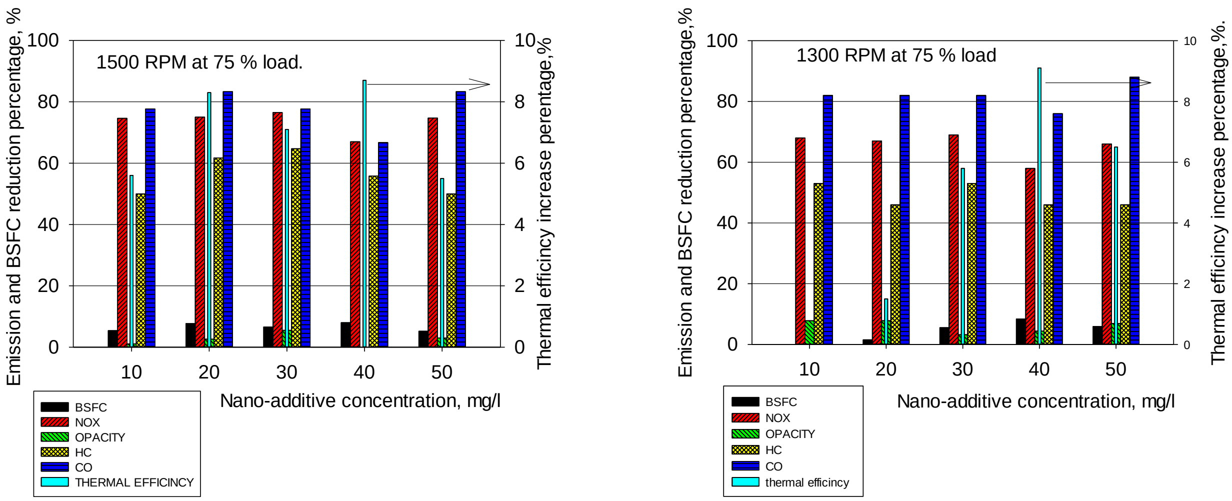

Figure 10: The reduction percentage of both BSFC and emissions (NO_x, HC, CO and smoke opacity), and the increase percentage of the engine thermal efficiency at engine load of 75 % full load at 1500 RPM and 1300 RPM versus nanoparticle dose relative to the corresponding values when biodiesel-diesel fuel is used

COCLUSION

The performance and emission characteristics of diesel engine running 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.
- It will be recommended a low dose of alumina nanoparticles in the range of 30 mg/l to achieve the best engine performance with optimal emission characteristics especially 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

References

[1] Atabani A.E., Mahlia T.M.I., Masjuki H.H., Badruddin I. A. A comparative evaluation of physical and chemical properties of biodiesel synthesized from edible and non-edible oils and study on the effect of biodiesel blending. Energy 2013;58:296-304.
[2] Atabani A.E., Silitonga A.S., Badruddin I.A., Mahlia T.M.I., Masjuki H.H., Mekhilef S. A comprehensive review on biodiesel as an alternative energy resource and its characteristics. Renewable and Sustainable Energy Reviews 2012;16:2070-2093.
[3] Bankovi´ c-Ili ´c I. B., Stamenkovi´c O. S., Veljkovi´c V. B. Biodiesel production from non-edible plant oils. Renewable and Sustainable Energy Reviews 2012;16:621-3647.
[4] Demirbas A. Political, economic and environmental impacts of biofuels: A review. Applied Energy 2009;86:108-117.
[5] Mujeebu M. A., Abdullah M.Z., Abu Bakar M.Z., Mohamad A.A., Muhad R.M.N., Abdullah M.K. Combustion in porous media and its applications – A comprehensive survey. Journal of Environmental Management 2009; 90: 2287–2312.

[6] Abd-elfatah M., Farag H.A., Ossman M.E. “Production of biodiesel from non-edible oil and effect of blending with diesel on fuel properties”. IRACST –Engineering Science and Technology: An International Journal ISSN 2012;2:2250-3498.
[7] Osayed S.M.A, Measurement of Laminar Burning Velocity of Jojoba Methyl Ester, M.Sc., Mattaria Faculty of Engineering, Helwan University 2001.
[8] Selim M. Y. E., Radwan M. S., Saleh H. E. On the Use of Jojoba Methyl Ester as Pilot Fuel for Dual Fuel Engine Running on Gaseous Fuels. SAE International 2007.
[9] Dawood .A. Effect Of Alternative Fuel On Internal Combustion Engine Performance And Pollution, M.Sc. Benha High Institute of Technology 2003. Egypt.
[10] ASTM Standard D7467–13," Standard Specification for Diesel Fuel Oil, Biodiesel Blend (B6 to B20)," ASTM International, West Conshohocken, United States, 2013, PA 19428-2959.
[11] Gan Y., ”Combustion and Evaporation Characteristics Of Fuel Droplet containing Suspended Energetic Nanoparticles”, PhD, Purdue University 2012.
[12] Tyagi H., Phelan P. E., Prasher R., Peck R., Lee T., Pacheco J. R., Arentzen P. Increased hot plate ignition probability for nanoparticle-laden diesel fuel. Nano Letters 2008; 8:1410-1416.
[13] Selvan A. M. V., Anand R. B., Udayakumar M., “Effects Of Cerium Oxide Nanoparticle Addition In Diesel and Diesel-Biodiesel-Ethanol Blends On The Performance And Emission Characteristics of a CI Engine. ARPN Journal of Engineering and Applied Sciences 2009; 4:1-6.
[14] Sajith V., Sobhan C.B., Peterson G.P. Experimental investigations on the effects of cerium oxide nanoparticle fuel additives on biodiesel. Advances in Mechanical Engineering 2010: ID 581407.
[15] Ganesh D., Gowrishankar G. Effect of Nano-fuel additive on emission reduction in a Biodiesel fuelled CI engine. IEEE 2011:3453-3459.
[16] Sadhik B. J., Anand R.B. Effects of Alumina Nanoparticles Blended Jatropha Biodiesel Fuel on Working Characteristics of a Diesel Engine. ISSN 0974-3146 2010; 2:53-62.
[17] Guru M., Karakaya U., Altiparmak D., Alicilar A. Improvement of diesel fuel properties by using additives. Energy Conversion & Management 2002; 43:1021–1025.
[18] Prajwal T., Eshank D., Banapurmath N.R., Yaliwal V.S. experimental investigations on a diesel engine fuelled with multiwalled carbon nanotubes blended biodiesel fuels. International Journal of Emerging Technology and Advanced Engineering (ICERTSD) 2013; 3:72-76.
[19] Kline S.J. The Purposes of Uncertainty Analysis. Transaction of ASME 1985; 107:153-160.
[20] Yetter R. A., Grant A. R., Steven F. S. Metal particle combustion and nanotechnology. Proceedings of the Combustion Institute 2009; 32:1819-1838.
[21] Kao M. J., Chen C. T., Bai F. L., Tsing T. T. Aqueous aluminium nanofluid combustion in diesel fuel. Journal of Testing & Evaluation 2008; 36:19428-2959.