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Experimental Investigation using CNTS as an Additive to Palm Biodiesel Blend on a DI Diesel Engine Performance, Emission and Combustion Characteristics

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Abstract: The continuous increase in energy demand, consumption of fossil fuels, harmful exhaust emissions and global warming, all these led to search about alternative fuel. This paper reports on the use of carbon nanotubes as additive to palm-biodiesel blended fuel and their effects on performance, exhaust emission and combustion characteristics of a single cylinder diesel engine. The used fuels in this study were neat diesel, biodiesel blend and CNTs-biodiesel blended fuel. Biodiesel was prepared from palm oil by transesterification process. Biodiesel blends have ASTM standards of physical and chemical characterization near to diesel fuel. Biodiesel blend was prepared from palm methyl ester and diesel fuel (20% palm methyl ester and 80% diesel fuel). The CNTs were blended with biodiesel fuel (B20) in the mass fractions of 25, 50, 75 and 100 ppm with the aid of a mechanical homogenizer and an ultrasonicator. Subsequently, the stability characteristics of CNT blended–biodiesel fuels were analyzed. The experimental investigations were carried out in a computerized single cylinder, 4-stroke diesel engine of 5.7 kW rated power. All the experiments were conducted at a constant speed of 1500 rpm at different engine loads. Experimental results show that performance and combustion characteristics were found to be comparable with diesel fuel. It was observed that Carbon nanotube additive to palm biodiesel blended fuel (B20) is efficient in improving performance and reducing the exhaust harmful pollutants in diesel engine. A dosing level of carbon nanotubes in the range of 100 ppm is recommended to achieve the best engine performance with optimal emissions reductions and combustion characteristics, particularly to remove the disadvantages related to use of biodiesel blends about diesel fuel.

Keywords: Carbon nanotubes, diesel engine, palm oil, biodiesel, performance, emissions.

I. INTRODUCTION

The global energy scenario and the technical community is presently confronted with fossil fuels diminution and environmental degradation, and thus oriented the researchers to direct active research interests in nonpetroleum, renewable and co friendly alternative fuels. Fuels of bio origin have provided solutions for fossil fuels depletion and environmental degradation. Biodiesel can be mixed with diesel oil to reduce exhaust emissions without affecting the engine efficiency [1-2]. The recent advances in nano science and nanotechnology proved that the nano energetic materials have great advantages over micro sized materials. Ignition delay and ignition temperatures are the significant parameters to characterize the performance of a diesel engine [3]. Nano particle blended fuels are known to exhibit significantly different thermo physical properties when compared to base fuels. At nano meters scale, the surface area to volume ratio of the particle increases considerably and this enables a larger contact surface area during oxidation process [4]. For instance, due to size-dependent properties, energetic materials containing nano-particles can release more than twice the energy of even the best molecular explosives [5].

Application of nanoscale energetic metal particle additives in liquid fuel is an interesting concept yet unexplored to its full potential. Such formulated nanofuels offer shortened ignition delay, decreased burn times and rapid oxidation which leads to complete combustion [6]. Nano additive enhances surface area to volume ratio and increases catalytic activity [7]. The peak pressure and the maximum rate of pressure rise were also low for the alumina/CNT nanoparticles blends due to shorten ignition delay [8, 9]. Dispersion of carbon nanotubes has improved the fuel properties of palm oil biodiesel fuel and its blends. Thermal conductivity, heating value and flash point have increased with higher dispersion concentration of carbon nanotubes [10]. CNT into diesel-biodiesel blends have altered the thermal-physical properties of the fuel, changes in key operational characteristics such as viscosity and density and improve the parameters for engine performance such as fuel spray characteristics, injection timing, level of emissions, power produced, and the torque generated [11].

Carbon nanotubes could act as a potential nano additive for the fuels. Carbon nanotubes enhances the burning rate of the fuel, improves the cetane number, acts as an antiknock additive and promote clean burning [12-14]. An experimental investigation was done on a single cylinder diesel engine using carbon nanotubes and Alumina nanoparticles as additives with diesel, biodiesel, water–diesel emulsion fuels. The results showed that an appreciable increase in brake thermal efficiency and reduced exhaust pollutants compared to diesel and biodiesel fuels [15, 16]. The suspended CNT in a base fluid enhances the surface area to volume ratio and settling time [17]. An experimental investigation on the performance and the emission characteristics of a diesel engine using CNT blended diesel was done. They observed a substantial enhancement in the brake thermal efficiency and reduced harmful pollutants compared to that of neat diesel. This is assumed to be due to better combustion [18]. An experimental investigation to determine performance, emission, and combustion characteristics of a single cylinder diesel engine using multi walled carbon nanotubes (MWCNTs) blended biodiesel fuels was carried out [19].

The biodiesel was prepared from Honge oil methyl ester. The MCNTs were blended with the biodiesel fuel in the mass fractions of 25 and 50 ppm. The results revealed that a considerable enhancement in the brake thermal efficiency and substantial reduction in the harmful pollutants due to the incorporation of MWCNTs in the biodiesel fuels were observed. The effect of carbon nanotubes (CNT) additive mixed in various proportions (100 to 300 ppm) with methyl ester of neem oil on performance and emissions in a computerized single cylinder diesel engine show that the nano additive was effective in improving the performance and controlling the NO emissions of methyl ester of neem oil fuelled diesel engine [20]. An experimental investigation was carried on a diesel engine using carbon multi walled nanotubes added with palm oil biodiesel and diesel blend (B20) in mass fractions of 20, 40, 60, 80 and 100 ppm. A significant reduction in specific fuel consumption and exhaust emission at all operating loads for carbon nanotubes blended biodiesel. Enhancement in thermal efficiency and heat release rate was shown due to effect of carbon nanotubes addition in biodiesel blend [21]. The suspended CNT in a base fluid enhances the surface area to volume ratio and settling time. The combustion behavior of diesel fuel with the addition of nanoscale energetic materials as fuel additives enhance the combustion and engine performance in a diesel engine. In addition, due to the small scale of nanoparticles, the stability of the fuel suspensions should be markedly improved. The changes in diesel fuel properties like viscosity, flash point and fire point, due to the introduction of carbon multiwalled nanotubes additive were observed. The diesel fuel with carbon multiwalled nanotubes additive presented a marginal improvement in engine performance [22].

The present work is aimed at establishing the effects on the performance, emission, and combustion characteristics of a single cylinder, direct injection diesel engine using CNTs blended palm–biodiesel fuel B20. Palm biodiesel was produced from palm oil by Transesterification process. Physical and chemical properties of palm biodiesel blend B20 was near to diesel fuel. The tested biodiesel blends were prepared by dispersing CNT into biodiesel blends at concentrations of 25, 50, 75 and 100 ppm, respectively and compared to palm biodiesel blend and diesel fuel. Performance parameters such as specific fuel consumption, thermal efficiency and exhaust gas temperature were studied. CO_2, NOx, HC and smoke emissions were compared to diesel fuel. Combustion characteristics such as cylinder pressure and heat release were compared to diesel fuel.

II. MATERIALS AND METHODS

A. *Nanoparticles Properties*

Nanotech Egypt Company supplies carbon nanotubes with 99% purity, with detailed specifications listed in Table 1. Scanning electron microscopy (SEM) provides direct examination of nanotube alignment and its size [23]. The morphology of nanoparticles was investigated by Scanning Electron Microscopy (SEM) (Model: Quanta FEG250) in Central labs, National Research Centre, Egypt. The SEM images showed that most of the nanoparticles obtained from all the ablated laser energies have tubular shape with a particle size of (L: > 660 nm) and (W: 20 ± 5 nm) SEM of carbon nanotubes is shown in Fig. 1. Surface and morphological characterization of carbon multiwalled nanotubes were carried out using Transmission Electron Microscope (TEM) (Model: JOEL JEM-2100). Nano sized tubular shaped carbon nanotubes obtained were confirmed as shown in Fig. 2.

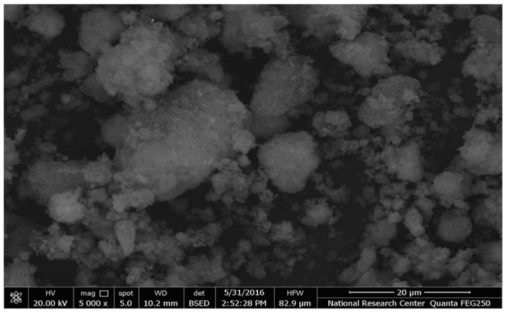


Fig.1. Scanning Electron Microscopy image of carbon nanoparticles

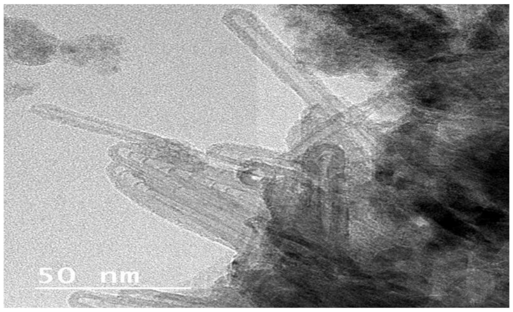


Fig.2. Transition Electron Microscopy image of carbon nanoparticles

Table 1: Carbon nanotubes specifications

Item	Specifications
Manufacturer	Nanotech company, Egypt
Appearance (color)	Black
Appearance (form)	Powder
Solubility	Dispersed in Water
Avg. Size (TEM)	(L: > 660 nm) and (W: 20 ± 5 nm)
Shape (TEM)	Tubular-like shape

B. Production of Palm Biodiesel

Palm methyl esters were produced at National Research Centre, Egypt using a 1 Litre batch reactor, a reflux condenser, a magnetic stirrer, a thermometer, and a sampling outlet. To produce palm biodiesel, crude palm oil was reacted with a 6:1 molar ratio of methanol to oil and 1% (by weight). Sodium hydroxide (NaOH) and maintained at 65 ◦C for 2 hr and a stirring speed of 600 rpm. After the reaction was complete, the methyl ester was kept in a separation funnel for 24 hr to separate glycerol from biodiesel. Then, the lower layer which contained impurities and glycerol was drained out, and the methyl ester was washed with warm distilled water (3 times) to remove unreacted methoxide. It was then heated to remove the water traces to obtain pure biodiesel. This process resulted in 92% yield of the methyl esters. The measurements of fuel properties of palm biodiesel and its blend with biodiesel B20 in comparison with that of diesel fuel according to ASTM D 6751-02 are shown in Table 2.

Table 2: Properties of diesel fuel, B100 and B20

Properties	Method	Diesel fuel	B100	B20
Kinematic viscosity, at 40ºC cSt	ASTMD445	4.5	5.6	5.2
Heating value MJ/kg	ASTMD270	42.73	39.52	41.45
Density, at 15ºC kg/m3	ASTMD1298	825	875	845
Cetane number	ASTMD613	50	58	53
Flash point ºC	ASTMD92	77	164	88
Pour point ºC	ASTMD97	-17	-8	-----
Cloud point ºC	ASTMD97	-12	-4	------

C. Preparation of Fuel Blends

Blending of carbon nano particles with palm biodiesel fuel is the most pivotal step in our study. We need important issues to alleviate through this blending procedure are to ensure that the nano particles are well dispersed in diesel fuel and to ensure that the clinker phenomenon does not occur wherein the nano particles stick together to form circular clusters due to the high temperature inside the engine cylinder and clog the nozzle. The fuel used in the current investigation is palm biodiesel blended fuel B20. The dosing levels of carbon nanotubes samples (by weight) in the base fuel were 25, 50, 75 and 100 ppm.

For blending carbon nanotubes with palm biodiesel B20, Nano additive is accurately weighed using a high precision electronic weighing balance and added to measured quantity of palm biodiesel blended fuel B20. To make the dosing level of 25 ppm, 0.025 g of carbon nanotubes is added to a sample of palm biodiesel blended fuel B20 with volume of 1 litre. Subsequently, to increase the dosing level of 50, 75 and 100 ppm, we have to increase to 0.050, 075 and 0.100 g/L. After the addition of carbon nanotubes, it is shaken well, and then it is poured into signification apparatus where it is agitated for about 45 min in an ultrasonic shaker making uniform suspension. The resulting nanoparticles biodiesel blended fuel B20 are symbolized as B20 + 25 CNT, B20 + 50 CNT, B20 + 75 CNT and B20 + 10 CNT indicating nano contents of 25, 50, 75 and 100 ppm in palm biodiesel B20, respectively. The surfactants Span80 and Tween80 were used in dispersing carbon nanotubes in biodiesel B20 for better stability. The CNT additive is subjected to stability testing by different characterization techniques such as sedimentation, TEM, and UV- Vis spectroscopy. A sample of the blended test fuels has been allowed in a long tube under static conditions to observe mixture stability and it was found that the sample stable for 30 days without phase separation as shown in Fig. 3. Transmission Electron Microscopy (TEM) images and UV-Vis spectroscopy of carbon nanotubes (having average size ~10±2 nm) dispersed in biodiesel B20 having 50 ppm for 30 days is given in Fig 4. TEM images confirm the dispersion stability of carbon nanotubes in biodiesel B20 which is further confirmed from the UV-Vis spectroscopy. The CNT additive is subjected to UV-Vis spectroscopy tests and the result on the variations of relative absorption with respect to wave length. It is found that maximum absorbency is occurred in the wavelength of 222 nm.

(a) Palm biodiesel B20 (b) prepared sample (c) 30 days

Fig.3:Photographic stability images of carbon nanotubes of 30 ppm volume fraction (a) palm biodiesel B20, (b) prepared sample and (c) 30 days sample.

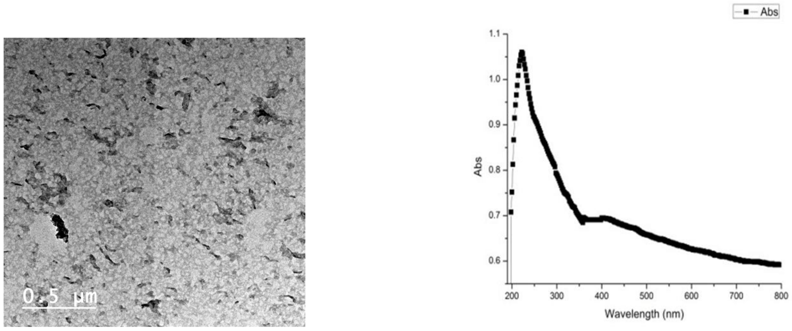


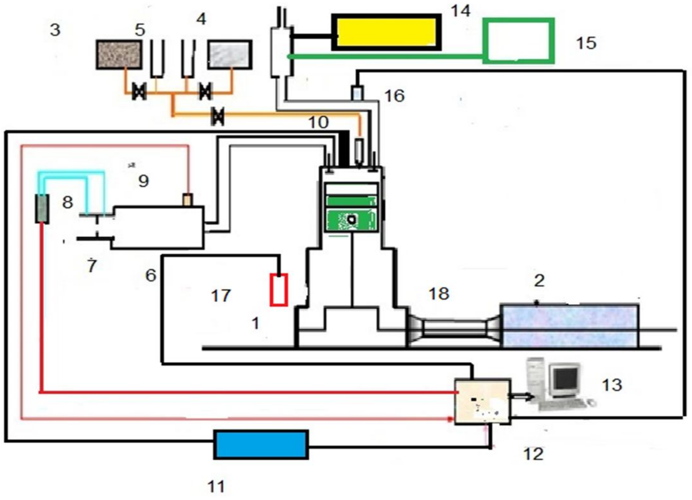
Fig.4: TEM micrographs and UV-Vis spectroscopy of carbon nanotubes of 50 ppm volume fraction with 30 days stability time.

III. EXPERIMENTAL SET UP AND METHODOLOGY

The experimental program was carried out using a single cylinder, four stroke, air cooled, direct injection (DI), naturally aspirated, diesel engine with a developing power of 5.775 kW at 1500 rpm at National Research Centre, Engine Research laboratory, Egypt. Figure 5 shows the engine test rig. The detailed specifications of the engine are listed in Table 3. AC generator of maximum electric power output of 10.5 kW equipped with a load controller and other auxiliary items have been coupled directly to the test engine to determine the engine output brake power. The intake airflow was measured by a sharp edged orifice mounted in the side of an air box coupled to the engine air inlet to dampen the pulsating airflow into the engine. A U- tube manometer was used to measure the pressure drop across the orifice. Calibrated thermocouple probes of type (K) were used for temperature measurements at different locations in the experimental set up; including: intake air manifold and exhaust gas. A selecting switch is used to switch among these thermocouples and the signals are readout by a digital thermometer. The crankshaft rotational speed was measured using speed tachometer. Two fuel tanks of 10 Liters capacity were mounted for storing the fuels on the rear side of the panel at highest position. One burette with stopcock and two way valves was mounted on the front side of the panel for fuel flow measurements and selecting between both diesel and biodiesel fuels. The fuel consumption was determined by measuring the time for the consumption of fixed fuel volume (20 ml). For recording the instantaneous in cylinder pressure, a water cooled Kistler piezoelectric pressure transducer (model 601A) measure from 0 to 250 bar as pressure range with sensitivity of 16.5 pc/bar and accuracy of 1.118% connected with Nexus charge amplifier (2692-A-0S4) were used. The piezoelectric pressure transducer was flush mounted with the cylinder head to measure the cylinder pressure. The flush mounting was preferred to minimize the lag in the pressure signal and avoid pipe connecting passage resonance. The instantaneous position of the piston top dead center (TDC) was determined using a proximity switch (Type LM12-3004NA) fixed on the output shaft of the engine. In order to guarantee confidence in the combustion diagnosis results, the combustion pressure data were averaged over 120 consecutive engine cycles. In all the cases, the pressure crank angle diagrams were recorded and processed, to get the combustion parameters by the data acquisition system. High speed data was acquired using LABVIEW software and national instruments data acquisition system (NI-USB-6210) for later analysis. OPA 100 smoke meter and MRU DELTA 1600-V gas Analyzer were used for the measurements of smoke opacity and exhaust gas concentrations. The accuracy and reproducibility of the instrument was ±1% of full scale reading. The measurement principle for CO, HC, CO_2 were infrared measurement and for NO and O_2 were electrochemical measurement. Digital readouts of CO and NO_X, HC, CO_2 and O_2 are available through the gas analyzer screen after steady state conditions and the average was taken for fifth minutes. Tests were executed without carrying out any modification on the engine or its fuel injection system (mass injected or injection timing). The experiment was carried out by varying engine load from zero to full load by maintaining constant rated speed of 1500 rpm throughout the experiment. The injection timing was 24º BTDC at an injection pressure of 175 bar and compression ratio was 17.5:1. The engine trial was conducted as specified by IS 10,000. In each test, the performance and emission measurements were triplicated. All the equipments were calibrated in accordance to the respective manufacturer's specifications, prior to conducting the tests. All the tests are carried out three times under steady state condition and the observed uncertainties for NO, unburned HC, CO, Smoke opacity and BTE are ±1 ppm, ±1 ppm, ±0.01 % Vol., ± 1 % and ± 1.5 %, respectively. The maximum uncertainty in measurement of brake power, brake specific fuel consumption, and engine speed are found to be 0.85 %, 2.2 % and 0.15 % (± 2 rpm), respectively. The engine was run with diesel fuel for several minutes to warm it up before the biodiesel fuels were tested. Likewise, the engine was operated with diesel fuel before it was shut down. The same procedure was used for B20 fuel and palm-CNTs blended fuels test to blush out the nanoparticles-blended biodiesel fuels from the fuel line systems. To carry out engine performance and emission tests, the engine was run at constant engine speed of 1500 rpm at various loads and followed the SAE J1515 MAR88 procedure.

Engine parameters	Specifications
Type	DEUTZ F1L511
Number of cylinders	1
Number of Cycles	Four stroke
Cooling type	Air cooled
Bore (mm)x Stroke (mm)	100 x105
Compression ratio	17.5:1
Fuel injection advance angle	24º BTDC
Rated brake power (kW)	5.775 at 1500 rpm
Number of nozzle holes	1
Injector opening pressure (bar)	175

Table 3: Engine specification



1. Diesel engine
2. AC generator
3. Diesel tank
4. Biodiesel tank
5. Burette
6. Air surge tank
7. Orifice
8. Pressure differential meter
9. Intake air temperature thermocouple

10- Piezo pressure trnsducer
11- Charge amplifier
12- Data acquisition card
13- Personal computer
14- Exhaust gas analyzer
15- Smoke meter
16- Exhaust gas temperature thermocouple
17- Proximity switch
18- Cardan shaft

Fig. 5: Schematic diagram of the experimental setup.

IV. RESULTS AND DISCUSSIONS

A. Specific Fuel Consumption

Figure 6 shows the variation of specific fuel consumption with engine brake power. It is observed that specific fuel consumption for B20 biodiesel is more than that of neat diesel fuel due to its higher viscosity (nearly twice diesel fuel), lower volatility and lower calorific value. The addition of CNT additive decrease specific fuel consumption for all biodiesel blends compared to B20 biodiesel fuel for all engine loads. This reduction in specific fuel consumption may be due to improved atomization and better mixing process. Specific fuel consumption decreases with the increase in the dosing level of CNT. The decrease in specific fuel consumption can be due to the positive effects of nanoparticles on physical properties of the fuel and reduction of ignition delay time which leads to better combustion [24]. The maximum specific fuel consumption for diesel, B20, B20+ 25 CNT, B20+ 50 CNT, B20+ 75 CNT and B20+100 CNT at full load are 0.367, 0.449, 0.431, 0.407, 0.390 and 0.378 kg/kW.hr.

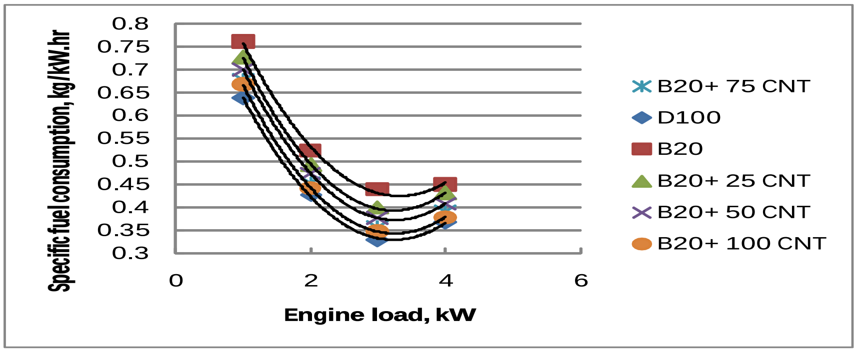


Fig. 6: Variation of specific fuel consumption with engine load.

B. Thermal Efficiency

The thermal efficiency indicates how efficiently energy in the fuel is converted into mechanical output. Figure 7 portrays the variation of thermal efficiency with engine load for palm biodiesel B20 and palm-CNTs blended fuels and diesel fuels. The thermal efficiency for diesel fuel is 25.4% at full load, which is the highest among all fuels tested. Moreover, the figure illustrates that thermal efficiency for B20 operation resulted in inferior performance due to higher density and poor volatility. The results show that the thermal efficiency of a diesel engine is improved by the addition of CNT in the palm biodiesel fuel B20. This could probably be attributed to the better combustion characteristics of CNTs. In general, the nanosize particles possess higher surface area and reactive surfaces that contribute to higher chemical reactivity to act as a potential catalyst [25]. In this perspective, the catalytic activity of CNTs could have improved due to the existence of high surface area and active surfaces. Due to this effect, the thermal efficiency is higher from additive addition. The maximum thermal efficiency for diesel, B20, B20+ 25 CNT, B20+ 50 CNT, B20+ 75 CNT and B20+100 CNT fuels at full load are 23.3, 19, 20, 21, 22.3 and 23%. It has been observed that the improvement in thermal efficiency increases with the dosing level of carbon nanotubes. A maximum increase of 1.5% in thermal efficiency was obtained when the dosing level of CNT is 100 ppm. Hence the performance of diesel engine with palm-CNTs blended fuels is comparable to that of diesel engine.

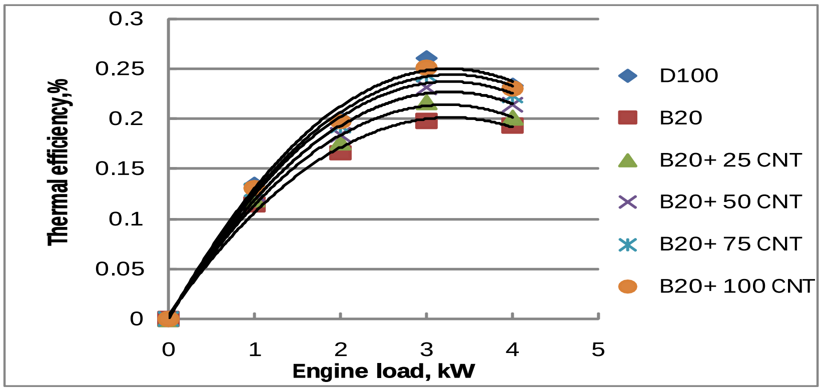


Fig.7: Variation of thermal efficiency with engine load.

C. Exhaust Gas Temperature

The variation of exhaust gas temperature with respect to engine load is shown in Fig. 8. The exhaust gas temperature is an indicator of heat loss of fuels tested from diesel engine [9]. Exhaust temperature increases with the increase in brake power in all cases. The increase in exhaust gas temperature with engine load is clear from the simple fact that, more amount of fuel is required by the engine to produce the extra power which is also needed to take up the additional loading. From the reading, it can be seen that the exhaust gas temperatures of B20, B20+ 25CNT, B20+ 50CNT, B20+ 75 CNT and B20+100 CNT at full load are 333, 320, 315, 310 and 305^{o}C. which are higher than that of diesel fuel. Slight increase in exhaust gas temperature of B20 biodiesel fuel is due to higher viscosity and poor volatility which leads to late burning that causes increase in exhaust gas temperature. Palm-CNTs blended biodiesel blend fuels has less exhaust temperatures than biodiesel blend B20 for any brake power due to improved combustion, higher thermal efficiency and the decrease of heat loss in exhaust content.

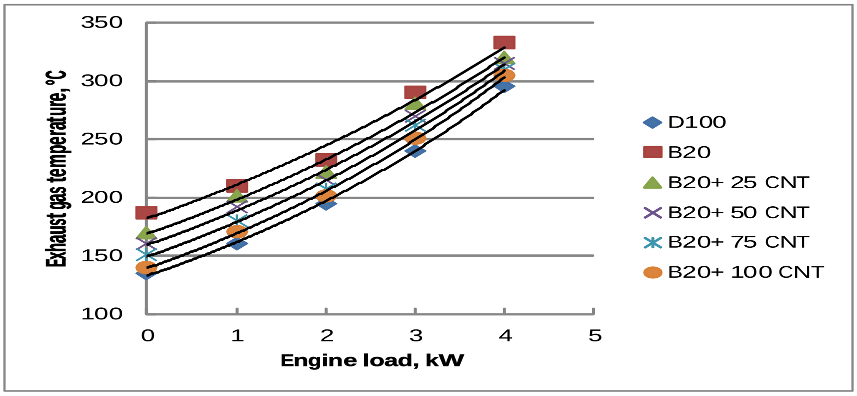


Fig.8: Variation of exhaust gas temperature versus engine load.

D. Carbon Dioxide (CO_2) Emissions

Effect of carbon nanotubes blended biodiesel on carbon dioxide (CO_2) emission at different engine loads for all tested fuels is shown in Fig.9. CO_2 emissions for palm biodiesel blended fuel B20 was higher than that of diesel fuel this may be attributed to oxygen content in biodiesel fuel. At the same time, there was a slight rise in CO_2 emissions for the palm-CNTs blended fuels than B20 blend and neat diesel fuel. The higher catalytic activity and improved combustion characteristics of CNTs leading to improved combustion could be the reason for CO_2 emission reduction. CO_2 emissions for B20+ 25 CNT, B20+ 50 CNT, B20+ 75 CNT and B20+100 CNT are 4.5, 4.7, 4.9 and 5.2% compared to 4.3% for B20 biodiesel blend and 4% for neat diesel fuel at the full load respectively. Increase of CNT dosing led to increase of CO_2 emissions compared to palm biodiesel blend and diesel fuels.

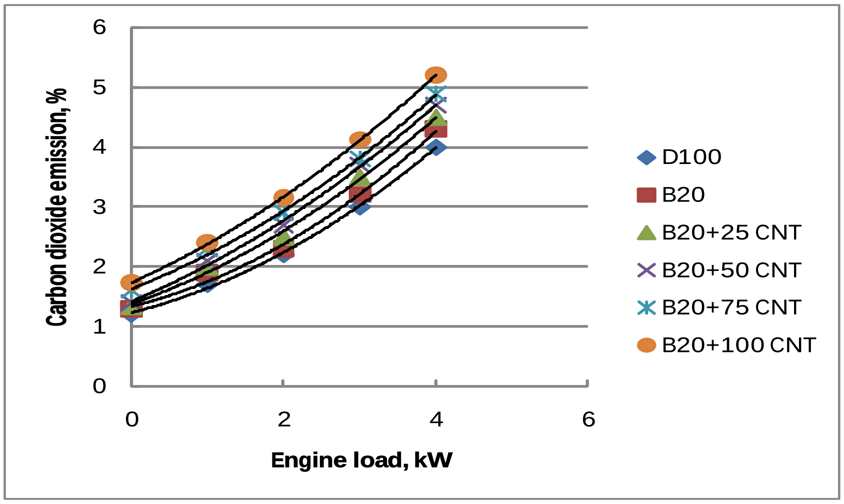


Fig.9: Variation of CO_2 emission versus engine load.

E. Hydrocarbon (HC) emissions

The variation of hydrocarbon emission with engine brake power for all tested fuels is shown in Fig.10. From the figure, it can be seen that hydrocarbon emissions for all fuels is lower than diesel fuel. However HC emissions are marginally lower for the palm-CNTs blended fuels than biodiesel blended fuel (B20) and diesel oils. This could be due to the intensive secondary atomization and significant fuel distribution in the presence of carbon nanotubes in the combustion chamber and thereby causing the hydrocarbon oxidation. Moreover the catalytic activity and improved combustion characteristics of carbon nanotubes promoting complete combustion. HC emissions values for diesel, B20, B20+ 25 CNT, B20+ 50 CNT, B20+ 75 CNT and B20+100 CNT at full load are 22, 19, 17, 15, 14 and 13 ppm at full load, respectively. Increase of CNT dosing led to decrease of HC emissions compared to palm biodiesel blend and diesel fuels.

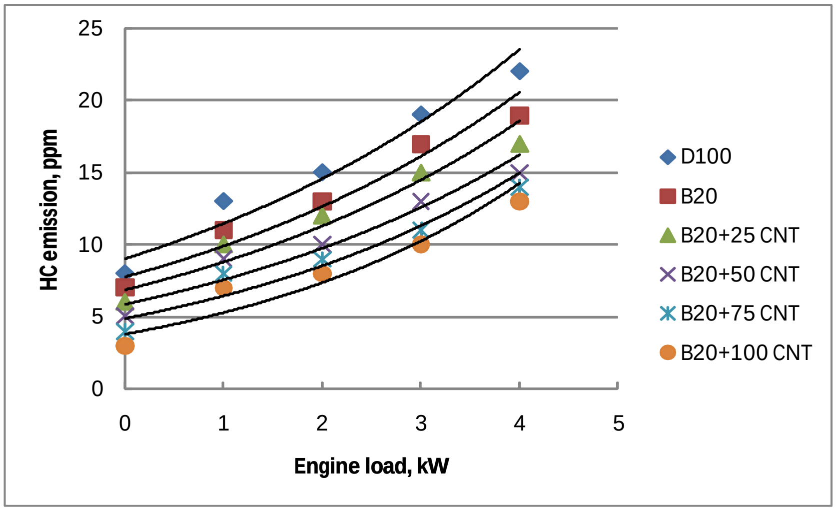


Fig.10: Variation of HC emission versus engine load.

F. NOx Emissions

Figure 11 shows the variation of NOx emission with brake power for diesel, palm biodiesel B20, and palm-CNTs blended fuels. The results show that NOx emission increases with the increase of engine load due to increase of fuel consumption and cylinder temperature. For B20 operation, NOx emissions were higher as compared to diesel operation. The reason is that biodiesel is an oxygenated fuel and possesses a shorter ignition delay leads to higher NOx emission formation. Nitrogen oxides formation strongly depends on peak cylinder temperature which explains the observed phenomenon. NOx emissions were found to be generally decreased with the addition of carbon nanotubes compared to B20 biodiesel blend as shown in Fig.11. This may be attributed to the scavenging of nitric oxide radical by carbon nanotubes, improved combustion, better homogenization of reactant mixture and reduced cylinder gas temperature inside the combustion chamber. It was also observed that the reduction in NOx emission increases with the increase in the dosing level of CNTs. This is due to the effect of oxygenated additives enhances combustion of fuels with the help of catalyst effect of CNT particle additions, which promotes heat transfer in the combustion chamber. NOx emissions values at full load for diesel, B20, B20+ 25 CNT, B20+ 50 CNT, B20+ 75 CNT and B20+100 CNT at full load are 196, 259, 245, 230, 215 and 205 ppm, respectively.

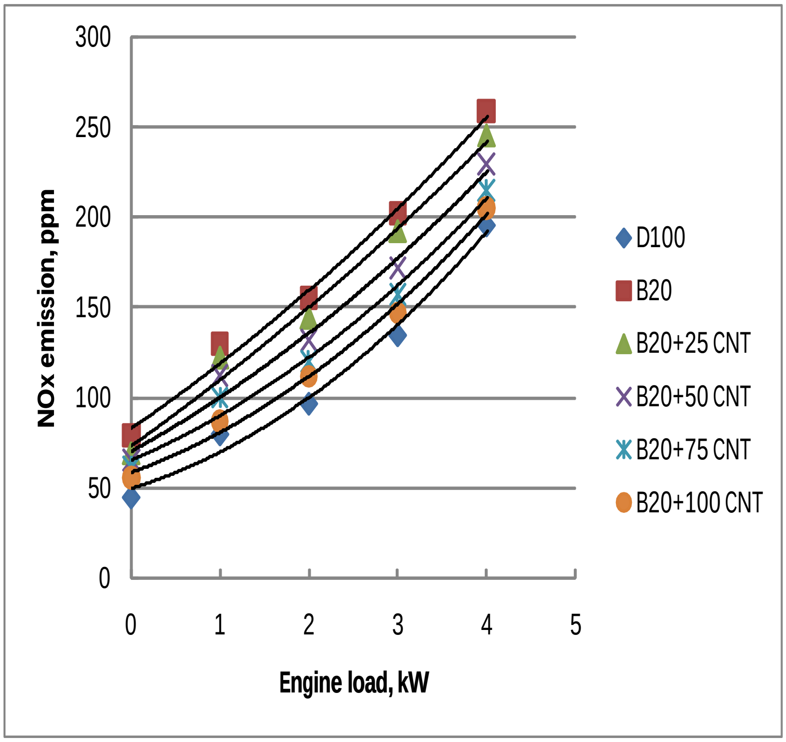


Fig. 11: Variation of NOx emissions versus engine load.

G. Smoke Opacity

The variations of smoke opacity with brake power for palm biodiesel blended fuel (B20), palm-CNTs blended biodiesel and diesel fuels are shown in Fig.12. Results show that smoke intensity increases for all fuels with the increase of engine load. This increasing trend is attributed to the increase in fuel consumption with the engine power output, presence of branched and ring structures can increase the smoke levels. From Fig.12, it is observed that palm biodiesel blended fuel (B20) operation resulted in slightly lower smoke opacity compared to neat diesel fuel. The opacity reduction could be attributed to shorter ignition delay characteristics and the inbuilt oxygen of biodiesel fuel which results in better combustion. However the smoke opacity of B20 was decreased with the addition of CNT. Reduction could be attributed to short ignition delay and the improved ignition characteristics of CNT nanoparticles leading to higher catalytic activity due to their higher surface to volume ratio and enhancing fuel air mixing in the combustion chamber. It was also observed that the reduction in the smoke density increases with the increase in the concentration of CNTs. Smoke opacity values for diesel, B20, B20+ 25 CNT, B20+ 50 CNT, B20+ 75 CNT and B20+100 CNT at full load are 79, 71, 67, 63, 60 and 57% at full load, respectively.

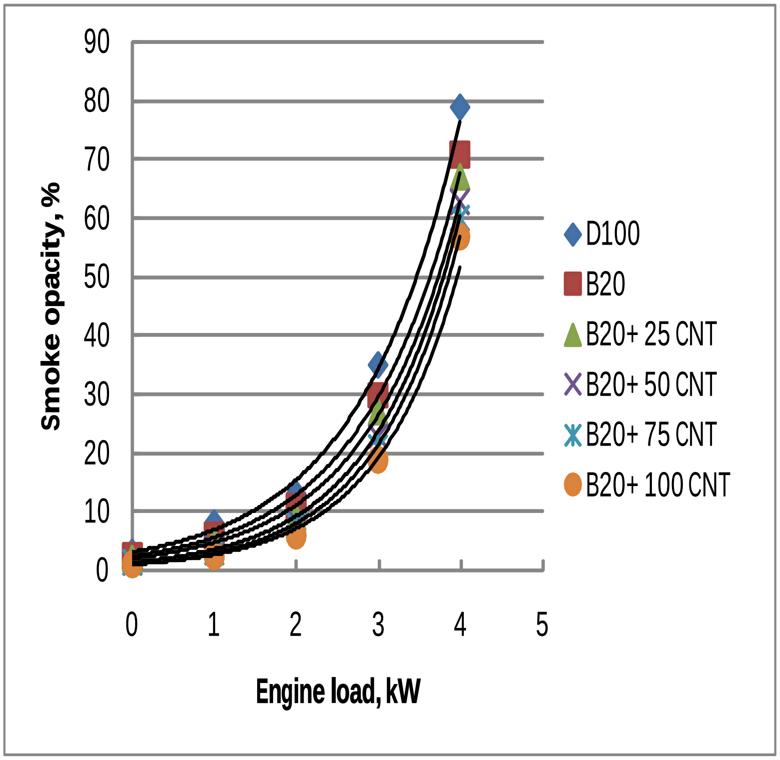


Fig.12: Variation of smoke opacity versus engine load.

H. Combustion Characteristics

Variation of cylinder pressure and heat release rate with respect to crank angle for all test fuels at full load is shown in Fig.13 and Fig.14, respectively. All tested fuels followed a cylinder pressure and heat release rate pattern similar to diesel fuel. Nano additives have an effect on the heat transfer rate during fuel atomization and evaporation. It is clear from the figures that the start of the combustion process in the cylinder was remarkably advanced. Heat release rate and cylinder gas pressure characteristics were lower for B20, B20 + 25 CNT, B20 + 50 CNT, B20 + 75 CNT and B20 + 100 CNT compared to biodiesel blend and diesel fuel. Figure 13 shows the variation of cylinder pressure with crank angle for diesel and palm biodiesel blend B20 with different dosing levels of the CNT at different engine operating conditions. Lower cylinder pressure was observed for palm biodiesel blend with diesel (B20) compared to diesel fuel due to the rich oxygen content of biodiesel causing sudden burning of fuel during the uncontrolled combustion phase and reduction of biodiesel heating value compared to diesel fuel. Addition of carbon nanoparticles tends to reduce the ignition delay [26]. From the figure, it is seen that the peak cylinder pressures for diesel fuel and biodiesel blend B20 were 74.3 and 73.6 bar were attained at a crank angle of 4° after TDC. In case of B20+ 25 CNT, the cylinder peak pressure of 72.7 bar was achieved at crank angle of 3° after TDC. In case of B20+ 50 CNT, the cylinder peak pressure of 71.2 bar was achieved at crank angle of 2° after TDC. In case of B20+ 75 CNT, the cylinder peak pressure of 69 bar was achieved at crank angle of 2° after TDC. In case of B20+ 100 CNT, the cylinder peak pressure of 67.5 bar was achieved at crank angle of 2° after TDC. It is clear that the cylinder pressure slightly decreased with the increase in CNT in biodiesel fuel. Figure 14 illustrates heat release pattern with respect to crank angle at full load. Heat release diagram is a quantitative description of timely burning of fuel in diesel engine. It is apparent from the figure, that the addition of nanoparticles enhances higher carbon combustion activation and hence promotes complete combustion [27]. The nanoparticle blended fuels showed accelerated combustion due to the shortened ignition delay. Due to shortened ignition delay, the degree of fuel-air mixing and uniform burning could have improved [28]. The results show that the heat release rate was found to be generally decreased with the addition of CNT to palm biodiesel blend B20. This is due to premixed and uncontrolled combustion phase. This could be due to higher cetane number, enhanced surface area to volume ratio, higher evaporation rate and the improved ignition properties of nanoparticle. It can be observed from the figure that the maximum heat release rate for D100, B20, B20+ 25 CNT, B20+ 50 CNT, B20 + 75 CNT, B20+ 100 CNT and diesel fuels were 40.2, 39.6, 39.1, 38.3, 37.1 and 36.3 kJ/Degree, respectively.

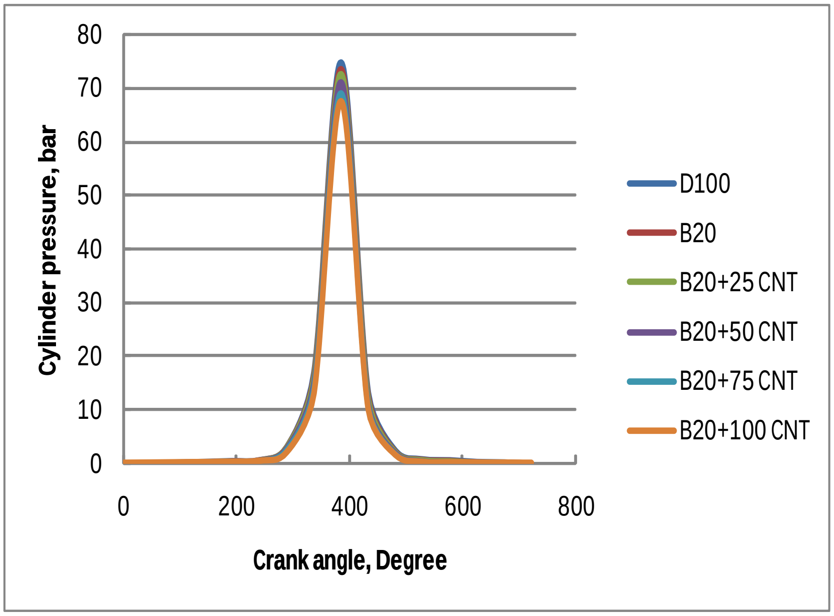


Fig. 13: Variation of cylinder pressure versus crank angle at full load.

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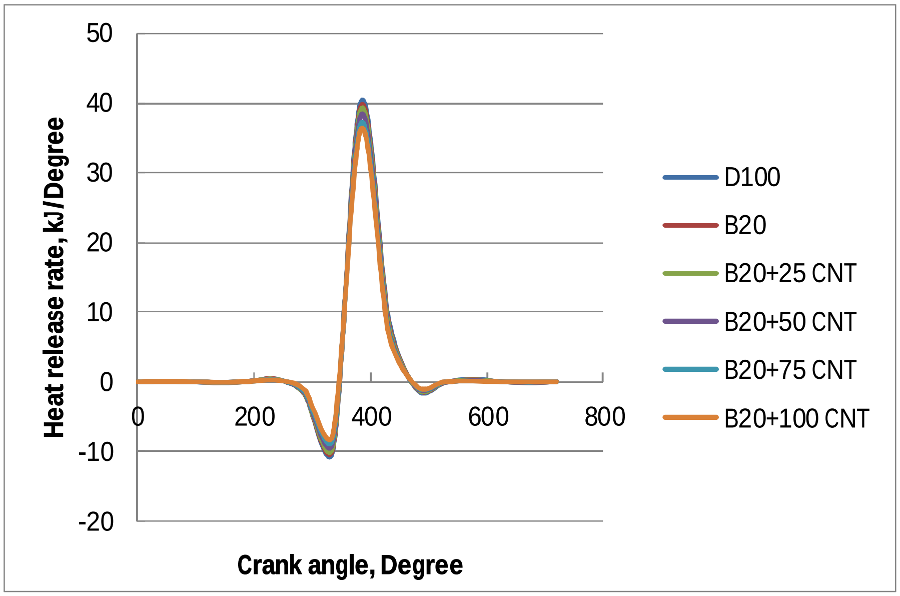


Fig. 14: Variation of heat release rate versus crank angle at full load.

V. CONCLUSIONS

Performance, exhaust emissions and combustion characteristics of palm-CNTs blended fuels were investigated in a single cylinder, constant speed, direct-injection diesel engine. Based on the experimental data, the following conclusions have been drawn:

A. Engine tests with the modified biodiesel with CNTs at different dosing levels of 25, 50, 75 and 100 ppm showed that thermal efficiency was relatively better as compared to that of palm biodiesel fuel and neat diesel fuel at optimized operating conditions.

B. Exhaust gas temperature for carbon nanotubes blended palm biodiesel B20 is less than that of biodiesel fuel due to lower viscosity, improved combustion, higher thermal efficiency and decrease of heat loss in exhaust gases provided by the blends which increases better combustion.

C. Exhaust emission levels of hydrocarbon and NOx are appreciably reduced with the addition of CNTs. It is understood that CNTs being thermally stable promotes the oxidation of hydrocarbon and reduction of nitrogen oxide, thus acting as an effective catalyst, when added in the nano particle form. Increase of CNT dosing in biodiesel blend led to increase of CO_2 emissions compared to palm biodiesel blend and diesel fuels

D. The smoke density of diesel was decreased on addition of carbon nanotubes by about 10-20%, especially at full load due to higher catalytic activity, higher surface to volume ratio and enhancing fuel air mixing in the combustion chamber

E. Carbon nanotubes blended biodiesel fuel showed lower cylinder gas pressure and heat release rate at optimized operating conditions.

F. Carbon nanotube additives to palm biodiesel blended fuel is efficient in improving performance and reducing the exhaust harmful pollutants from diesel engine. A dosing level of carbon nanotubes in the range of 100 ppm is recommended to achieve the best engine performance with optimal emissions reductions and combustion characteristics, particularly to remove the disadvantages related to use of biodiesel blends about diesel fuel.

REFERENCES

[1] A. BulentKoc, Mudhafar Abdullah," Performance and NOx emissions of a diesel engine fueled with biodiesel–diesel–water nano emulsions", Fuel Process. Technol. 109 (2013), pp.70–77.

[2] Mohammed EL-Kasaby, Medhat A. Nemit-allah," Experimental investigations of ignition delay period and performance of a diesel engine operated with Jatropha oil biodiesel", Alexandria Eng. J. 52 (2013), pp.141–149,

[3] C. Syed Aalam, C.G. Saravanan, M. Kannan, " Experimental Investigation on CRDI System Assisted Diesel Engine Fulled by Diesel with Nanotubes", American Journal of Engineering and Applied Sciences, Vol.15, No.3, pp.380-389, 2015 .

[4] Rossi C, Zhang K, Estève D, Alphonse P, Tailhades P, Vahlas C., " Nanoenergetic materials for MEMS: a review", J Micromech. System 2007, 16:919-931.

[5] Sun J, Simon SL.," The melting behavior of aluminum nanoparticles", Thermochimica Acta 2007, 463:32-40.

[6] Rakhi, N.M., Mousumi, C. and Parimal, A.P.," Nanofuels: Combustion, engine performance and emissions", Fuel, 2014, 120, 91–97.

[7] Karthikeyan, S., Elango, A. and Prathima, A.," Performance and emission study on zinc oxide nano particles addition with pomolion stearin wax biodiesel of CI engine", Journal of Scientific & Industrial Research, 2014, 73, 187-190.

[8] Varatharajan, K. and Cheralathan, M.," Effect of aromatic amine antioxidants on NOx emissions from a soybean biodiesel powered DI diesel engine", Fuel Processing Technology, 2013, 106, 526-532.

[9] Sadhik Basha, J. and Anand, R. B.," Role of nanoadditive blended biodiesel emulsion fuel on the working characteristics of a diesel engine", Journal of Renewable and Sustainable Energy, 2011, 3, 1-17.

[10] A. B. S. Alias, D. Thegaraju, K. V. Sharma, " Effect of carbon nanotube dispersions to the palm oil diesel–biodiesel blend properties ", International Conference on Mechanical Engineering Research (ICMER2013), 2013

[11] Halek, F., Kavousi, A. and Banifatemi, M., "Biodiesel as an alternative fuel for diesel engines", World Academy of Science, Engineering and Technology, 57, 2009.

[12] R.A. Yetter, G.A. Risha, S.G. Son," Metal particle combustion and a nano technology", Proc. Combust. Inst. 32 (2009) 1819–1838.

[13] F. Arianna, Covadonga Astorga, Giorgio Martini, Urbano Manfredi, Anne Mueller, Maria Rey, et al," Effect of water/fuel emulsions and a cerium-based combustion improver additive on HD and LD diesel exhaust emissions", Environ. Sci. Technol. 39(2005) 6792–6799.

[14] David Moy, Chunming Niu, Howard Tennent et al.," Carbonnano tubes in fuels", US Patent 2002-6419717, 2002.

[15] J. Sadhik Basha, R.B. Anand," An experimental investigation in a diesel engine using carbon nanotubes blended water–diesel emulsion fuel", Proc. IMechE, Part A: J. Power Energy 225(2011) 279–288.

[16] J. Sadhik Basha, R.B. Anand, "An experimental study in a CI engine using nanoadditive blended water–diesel emulsion fuel", J. Green Energy 8 (2011) 332–348.

[17] Marquis, E. D. S. and Chibante, L.P.F., "Improving the heat transfer of nanafluids and lubricants with carbon nanotubes", J.Miner, Metals Mater, Society, 2005 57, 32, 43.

[18] Sadhik Basha, J. and Anand, R. B. Performance and emission characteristics of a DI compression ignition engine using carbon nanotubes blended diesel. In proceedings of the International Conference on advances in mechanical engineering, Surat, India, 3-5 August 2009, pp. 312-316.

[19] Prajwal Tewari, Eshank Doijode, N.R. Banapurmath, V.S., “Experimental Investigations On A Diesel Engine Fuelled With Multiwalled Carbon Nanotubes Blended Biodiesel Fuels”, International Journal of Emerging Technology and Advanced Engineering, V 3(3), 2013,pp-72-76.

[20] G.Balaji, M.Cheralathan, "Effect of CNT as additive with biodiesel on the performance and emission characteristics of a DI diesel engine ", International Journal of ChemTech Research, Vol.7, No.3, pp 1230-1236, 2014.

[21] R.Senthilkumar, M.Prabu, "Performance and emission characteristics of single cylinder diesel engine using multiwalled nanotubes and karanga oil methyl ester ", Journal of Chemical and Pharmaceutical Sciences, JCHPS Special No. 6, pp.109-114, 2015.

[22] Marquis, E. D. S. and Chibante, L.P.F.," Improving the heat transfer of nanafluids and lubricants with carbon nanotubes", J.Miner, Metals Mater, Society, 2005 57, 32, 43.

[23] Cao, A., C. Xu, J. Liang, D. Wu and B. Wei, 2001," Xray diffraction characterization on the alignment degree of carbon nanotubes", Chem. Phys. Lett., 344: 13-17.

[24] Karthikeyan, S., A. Elango and A. Prathima, 2014," Diesel engine performance and emission analysis using oil methyl ester with the nano sized zinc oxide particles", Ind. J. Sci. Indus. Res., 21: 83-87

[25] Aalam, C.S., C.G. Saravanan and M. Kannan, " Experimental investigations on a CRDI system assisted diesel engine fuelled with aluminium oxide nanoparticles blended biodiesel", Alexandria Eng. J., 2015

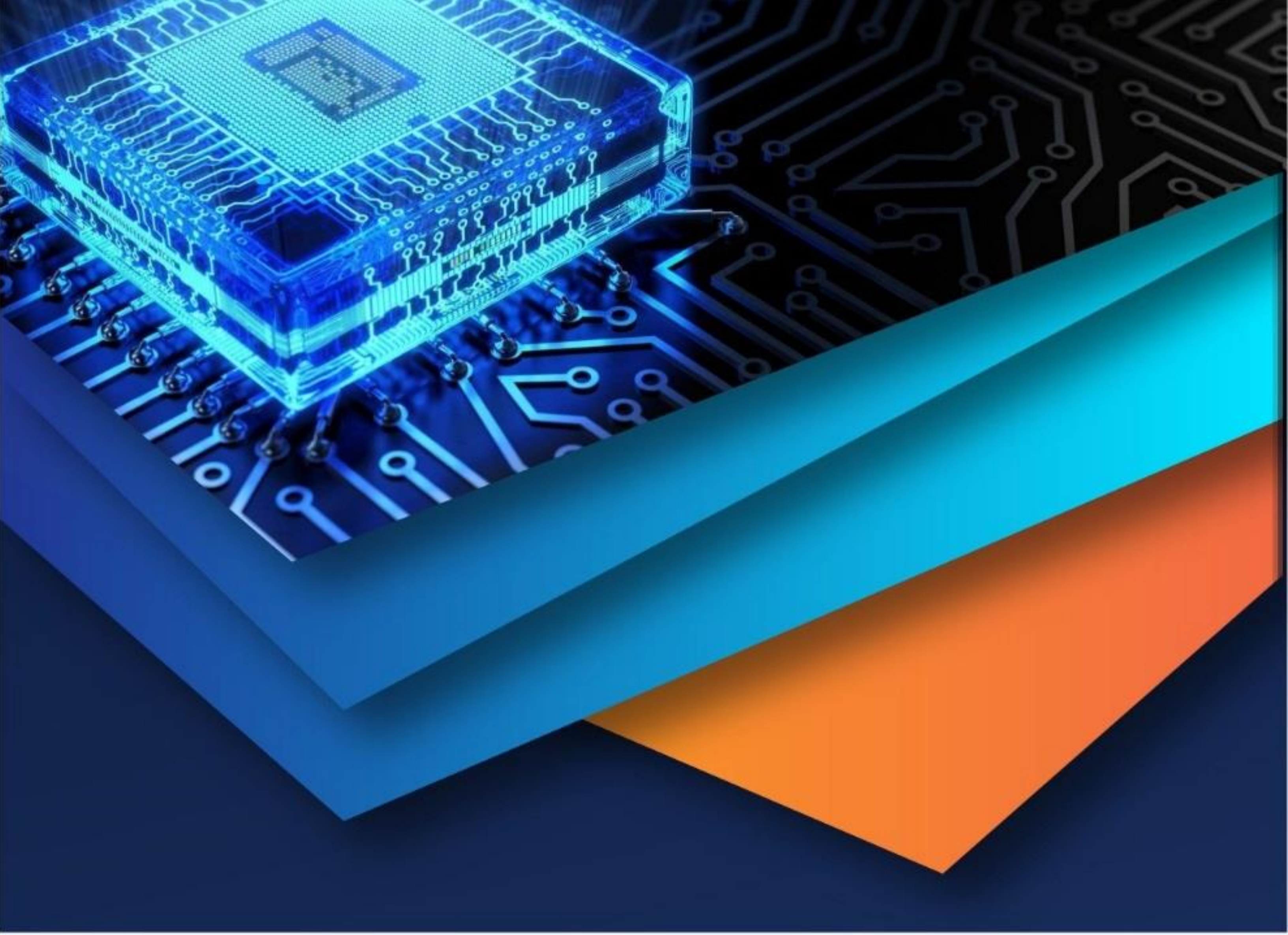
[26] Basha, J.S. and R.B. Anand, 2014. Performance, emission and combustion characteristics of a diesel engine using carbon nanotubes blended jatropha methyl ester emulsions. Alexandra Eng. J., 53: 259-273. DOI: 10.1016/j.aej.2014.04.001.

[27] Sajith, V., C.B. Sobhan and G.P. Peterson, 2010," Experimental investigations on the effects of cerium oxide nanoparticle fuel additives on biodiesel", Adv. Mech. Eng., 2010: 581407-581412.

[28] [28] Bahgat, M., A.A. Farghali, W.M.A. El Rouby and M.H. Khedr, 2011," Synthesis and modification of Multi- Walled Carbon Nano-Tubes (MWCNTs) for water treatment applications", J. Analytical Applied Pyrolysis, 92: 307-313. DOI: 10.1016/j.jaap.2011.07.002.

NOMENCLATURE

BTDC	Before top dead center
B20+ 25 CNT	Carbon nano tubes with mass fraction 25 ppm mixed with Palm biodiesel blend
B20+ 50 CNT	Carbon nano tubes with mass fraction 50 ppm mixed with Palm biodiesel blend
B20+ 75 CNT	Carbonnano tubes with mass fraction 75 ppm mixed with Palm biodiesel blend
B20+100 CNT	Carbon nano tubes with mass fraction 100 ppm mixed with Palm biodiesel blend
C.A.	Crank angle, Degree
CNT	Carbon nanotubes
CO_2	Carbon dioxide, %
NO_X	Nitric oxide, ppm
P_{cyl}	In-cylinder pressure, kPa
rpm	Revolution per minute
T_{exh}	Exhaust gas temperature, K
UHC	Unburned hydrocarbons, ppm



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