Indian Journal of Engineering & Materials Sciences
Vol. 21, February 2014, pp. 83-87

Diesel engine performance and emission analysis using canola oil methyl ester with the nano sized zinc oxide particles

S Karthikeyan[a]*, A Elango[b] & A Prathima[c]

[a]Department of Mechanical Engineering, Syed Ammal Engineering College, Ramanathapuram 623 502, India
[b]Department of Mechanical Engineering, Alagappa Chettiar College of Engineering and Technology, Karaikudi 630 004, India
[c]Department of Physics, Syed Ammal Engineering College, Ramanathapuram 623 502, India

Received 20 March 2013; accepted 24 October 2013

In this study, the performance, combustion and exhaust emission characteristics of single cylinder, four stroke, stationary, air-cooled and direct injection compression ignition engine have been investigated at the constant engine speed 1500 rpm under the full load when it is fueled with various blends such as 80% diesel + 20% canola oil methyl ester, 80% diesel + 20% canola oil methyl ester + 50ppm zinc oxide and 80% diesel + 20% canola oil methyl ester + 100ppm zinc oxide. And also the properties such as pour point, cloud point, flash point, kinematic viscosity, cetane number, sulphated ash and calorific value of above blends are determined and compared with American biodiesel standards (ASTM D7467). It is found that the addition of zinc oxide nanoparticles which accelerates early ignition of combustion shortens ignition delay and enhances NOx emissions.

Keywords: Diesel engine, Canola biodiesel, Nanoparticles, Ultrasonicator, Combustion characteristics, Fuel properties

Diesel has become an essential part of everybody's day-to-day life. It is found that diesel causes harmful effects to the environment. To overcome these effects, there is a need to find an alternative fuel like biodiesel. In the biodiesel, it is experienced that it too has some demerits. Addition of nanoparticles with biodiesel gives a good fuel to improve the combustion efficiency, combustion stability as well as reduce harmful emissions[1]. The scientists in nano science and technology council in USA have achieved to increase 10-25% combustion efficiency by adding 0.5% of aluminium nano-particles to a rocket's solid fuel. And also the combustion speed has been increased because of nanoparticle additives[2]. According to investigation the effect of aqueous aluminium nanoparticles in compression ignition engine, the aluminium nanoparticles have very high activity and can react with water at temperatures from 400°C to 660°C to generate hydrogen[3]. Aluminium nanoparticles serve as a catalyst to decompose the water. They also observed that the fuel consumption will reduce by using aluminium nanofluid and diesel mixture. The experimental investigation was carried out to improve the performance and emission characteristics of compression ignition engine using cerium oxide nanoparticles with diesel and biodiesel mixture fuel[4]. The cerium oxide acted as an oxygen donating catalyst and provides oxygen for the oxidation of carbon monoxide (CO) or absorbs oxygen for the reduction of nitrogen oxide (NO_x). In addition to that, they observed that the combustion of the fuel will improve and reduce the exhaust emission by using a cerium oxide nano particle. The burning characteristics of ethanol droplets containing nano and micro-sized aluminium particles were investigated[1]. They observed that the fuel burnt completely by suspending the aluminium nanoparticles with the fuel. According to earlier studies, it can be concluded that nanoparticle additives with biodiesel improve the engine performance and reduce the exhaust emissions. Ozsezen *et al.*[5] reported that when the test engine was fueled with COME instead of petroleum based diesel fuel, though exhaust emissions such as CO, HC, CO_2, smoke density are reduced considerably but increase the fuel consumption. Thus, it is of scientific interest to study the zinc oxide nanoparticles blended with COME. The nanostructured ZnO possess high surface area as well as good electrical, electrochemical and structural properties and it can be used as antibacterial agents[6]. Due to higher surface area of ZnO, the radius of the nanoparticle decreases. On decreasing the

*Corresponding author (E-mail: kamalipaper@gmail.com)

radius, the surface to volume ratio is increased leading to an increased rate of reaction and the concentration of the pollutants is decreased[7]. One of the drawbacks of combustion derived nanoparticles can be a health risk, if inhaled. Zinc oxide nanoparticles can be ingested directly when used in food, food packaging, drug delivery, and cosmetics. Suh *et al.*[8] evaluated the cellular effects of zinc oxide nanoparticles (50 and 100 nm diameter particle sizes) on the function of osteoblastic MC3T3-E1 cells. Zinc oxide nanoparticles showed cytotoxicity at concentrations of above 50 µg/mL, and there was no significant effect of the size on the cytotoxicity of zinc oxide nanoparticles. Finally, it can be concluded that ZnO nanoparticles can have protective effects on osteoblasts at low concentrations where there are little or no observable cytotoxic effects.

Materials and Methods

This study aims to test the performance and emissions of diesel engine using the various blends such as 80% diesel + 20% canola oil methyl ester (B20), 80% diesel + 20% canola oil methyl ester + 50ppm ZnO (D80B20ZnO50), and 80% diesel + 20% canola oil methyl ester + 100ppm ZnO (D80B20ZnO100). The canola biodiesel was supplied by Jatropha Oil Seed Development & Research Hyderabad, India. The diesel fuel was purchased from the open market. The ZnO nanoparticles of average size of less than 100 nm was supplied by the manufacturer M/s. Sigma-Aldrich [544906], USA. The nanoparticles are weighed by digital balance 0.001 g accuracy Shimadzu make, Model BL220H, 220g capacity. The preparation of above blends prepared with the aid of an ultrasonicator. The engine tests were performed on Kirloskar, single cylinder, four-stroke, air-cooled and a direct injection diesel engine. Tests were held on a laboratory test bed which consisted of a diesel engine, an electrical dynamometer and an exhaust emissions analyzer. The speed and load were recorded from digital indicator of the test ring. Fuel consumption was determined by weighing fuel used for a period of time on an electronic sensitive scale with using a chronometer.

Results and Discussion

Fuel properties

The performance, combustion and emission characteristics of the diesel engine using B20, (D80B20ZnO50), and (D80B20ZnO100) were investigated. The fuel properties of B20, D80B20ZnO50 and D80B20ZnO100 were determined in Sargam laboratory, Chennai, India and given in Table 1. It was observed that the ZnO nano additive blends showed slight improvement in calorific value and kinematic viscosity compared to B20. The higher calorific value indicates that lower fuel consumption and high viscosity lead to low atomization and high diffusion of the nozzle jet[9]. Based on this result, it is concluded that there is an improvement in fuel spray diffusion[10]. No significant differences were observed in the flash point, pour point, cetane number as calculated cetane index and sulphated ash due to the addition of ZnO nanoparticles in the blends.

Combustion characteristics

The variation of cylinder gas pressure and heat release rate with respect to crank angle for B20, D80B20ZnO50 and D80B20ZnO100 blends at full load is shown in Figs 1 and 2**.** It is examined that the maximum cylinder pressure is high for ZnO nano additive blends than B20. It means that the early initiation of combustion and the ignition delay decreases[**4**]. Figure 2 shows that the highest heat release rate is observed as 95.93 kJ/m^{3}deg for the ZnO nano additive (100ppm) blends than B20. Because of the rapid combustion takes place in the premixed phase[**4**].

Table 1 — Fuel properties of the tested fuels

Properties	Diesel	Canola oil	COME	B20	D80B20ZnO50	D80B20ZnO100	ASTM D7467
Density at 20°C (g/cm^3)	0.830	0.920	0.830	0.852	0.853	0.855	ASTM D4052
Kinematic viscosity at 40°C (mm^2/s)	4.0	37	5.5	3.7	3.8	4.0	ASTM D445
Flash point (°C)	50	220	183	48	49	51	ASTM D93
Pour & cloud point (°C)	-17	-12	-12 & -4	<-15	<-15	<-15	ASTM D97 ASTM D2500
Cetane number as calculated Cetane Index	40-50	40-50	6.28	55	56	56	ASTM D976
Sulphated ash	0.02	0.01	0.02	0.046	0.038	0.039	ASTM D482
Calorific value (kJ/kg)	42,000	35,000	38455	42278	42726	42931	ASTM D240

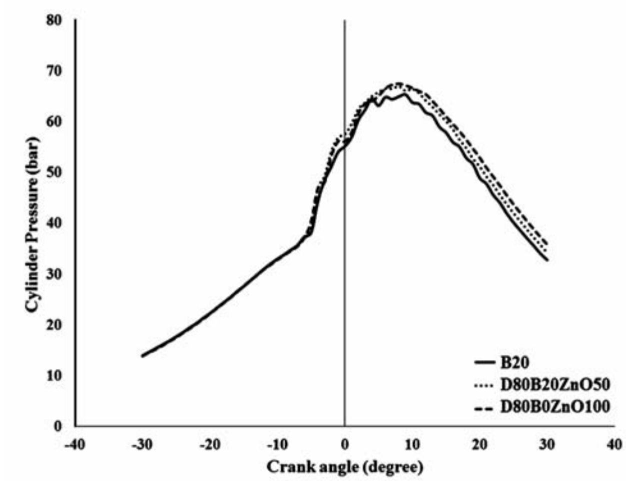

Fig. 1 — Variation of cylinder gas pressure with crank angle at full load

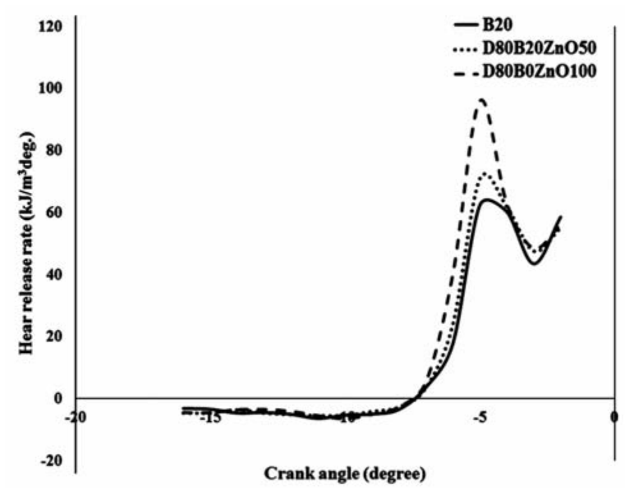

Fig. 2 — Variation of heat release rate with crank angle at full load

Performance characteristics

The brake specific fuel consumption (BSFC) of blends B20, D80B20ZnO50 and D80B20ZnO100 at varying brake mean effective pressure (BMEP) were shown in Fig. 3. It was observed that the BSFC value of D80B20ZnO50 and D80B20ZnO100 blends less than that of blend B20, because of improved atomization and better mixing process at higher injection pressure. The BSFC values for D80B20ZnO50 and D80B20ZnO100 blends decrease with increase in the dosing level of ZnO nanoparticle[9]. Based on the results, it is concluded that the decrease in BSFC can be due to the positive effects of nanoparticles on physical properties of fuel and also reduction of the ignition delay time. Figure 3

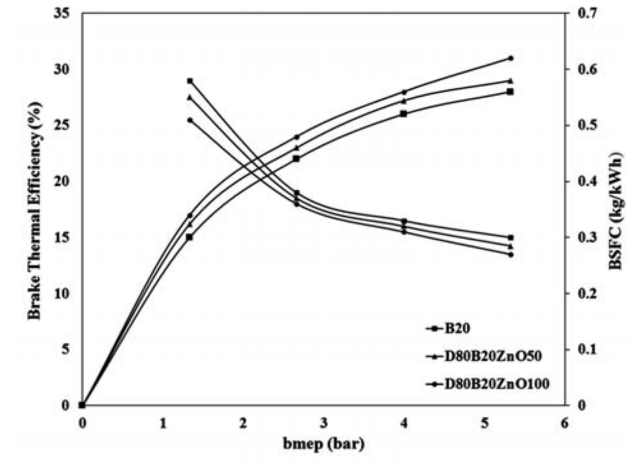

Fig. 3 — Variation of brake thermal efficiency and BSFC with BMEP

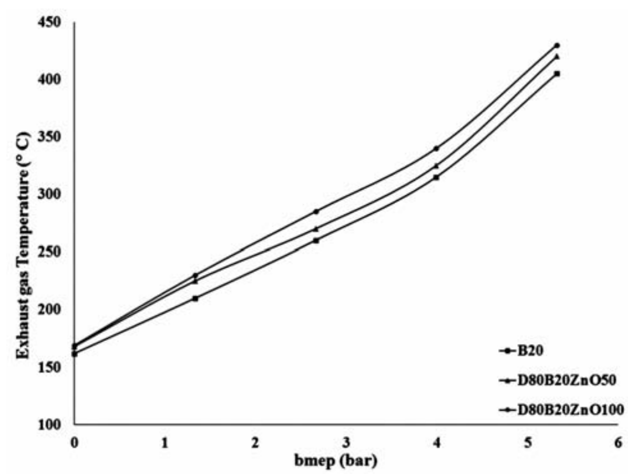

Fig. 4 — Variation of exhaust temperature with BMEP

also shows the brake thermal efficiency (BTE) for various fuel blends such as B20, D80B20ZnO50 and D80B20ZnO100 with respect to BMEP. It was observed that the BTE of the ZnO blended fuels is improved at higher loads and also found that the efficiency increases with the dosing level of nanoparticles. This could be probably attributed to better combustion characteristics of nanoparticles such as lighter surface area to volume ratio which is allowed more amount of fuel to react with air leading to enhancement in BTE. This result is also in agreement with the earlier reported results[11]. The variation of the exhaust gas temperature with respect to BMEP is shown in Fig. 4. It shows that the exhaust gas temperature increased with increasing oxygen level in fuels during the combustion[12,13]. From the figure, it is observed that the exhaust gas temperature

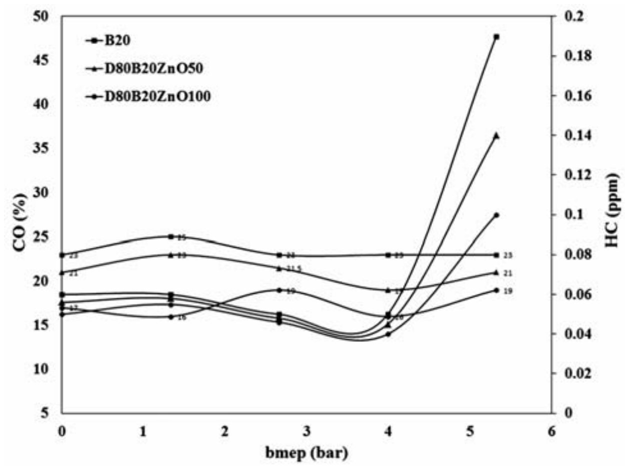

Fig. 5 — Variation of CO and HC with BMEP

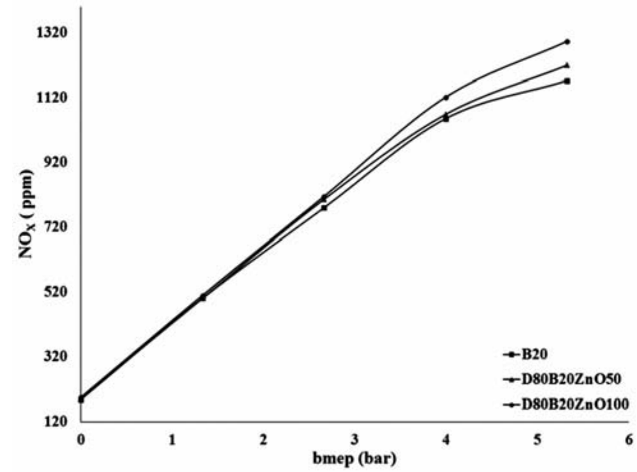

Fig. 6 — Variation of NO_x with BMEP

for zinc oxide nanoparticles blends was lower than that of B20. It is due to rapid evaporation, and in turn resulting reduced cylinder average temperature[14].

Emissions characteristics

Figures 5 and 6 show that the variation of CO, unburnt hydrocarbons (HC) and NO_x emissions for the different blends, respectively. It is observed that the minimum CO and HC emissions were measured with the use of ZnO blends compared to B20, while the maximum NO_x emission was recorded with the use of ZnO blended fuels. CO emission critically depends on the air to fuel ratio relative to stoichiometries proportions[15]. HC and CO emissions are found to be considerably reduced on the addition of the zinc oxide additive. This could be possibly attributed to the short ignition delay and the enriched ignition characteristics of alumina nanoparticles leading to high catalytic activity due to their higher surface to volume ratio and improving fuel air mixing in the combustion chamber and leads to improve combustion. Ignition delay may give a substantial effect on the exhaust emissions, because it controls the proportion of the fuel burnt. Increasing the burned fuel fraction in the premixed phase decreases unburned HC and CO emission, while increasing NO_x emission level. As mentioned in the combustion results, the ignition delay reduced when using ZnO blended fuels respectively compared to the B20 fuel. The shorter ignition delay advances the combustion duration, increases peak cylinder gas pressure and temperature and enhances NO_x emission were mainly caused by shorter ignition delays and early injection timings[3].

Conclusions

Experimental measurements and analysis of ZnO nanoparticle additives combustion in diesel fuel were carried out at different dosing levels of the nanoparticle additives. The ASTM standard tests for the fuel property measurements were reported in this paper for bio diesel modified by the addition of ZnO nanoparticles. The fuel characterization data showed some similarities and differences between B20 and B20 with nano additives. The ZnO nano additive blends show slight improvement in calorific value and kinematic viscosity compared to B20. It is found that the maximum cylinder pressure is high for ZnO nano additive fuels which speeds up the early initiation of combustion and the ignition delay decreases. The decrease in BSFC can be due to the positive effects of nanoparticles on physical properties of fuel and also reduction of the ignition delay time. The combustion characteristics improved by the lighter surface area to volume ratio of nano particles which is allowed more amount of fuel to react with air. It leads to enhancing in BTE. By and large, it is observed that the minimum CO and HC emission was measured with the use of ZnO blend fuels compared to B20, while the maximum NO_x emission was recorded with the use of ZnO blended fuels.

References

1 Senthilraja S, Karthikeyan M & Gangadevi R, *Nano Micro Lett*, 2 (2010) 306-310.

2 Jones M, Li1 C H, Afjeh A & Peterson G P, *Nanoscale Res Lett*, 6 (2001) 1-12.

3 Kao M J, Ting C C, Lin B F & Tsung T T, *J Test Eval*, 36 (2008) 186-190.

4 Arul Mozhi Selvan V, Anand R B & Udayakumar M, *J Eng Appl Sci*, 4 (2009) 1-6.
5 Ozsezen A N & Canakci M, *Energy Convers Manage*, 52 (2011) 108-116.
6 Nawaz H R, Solangi B A, Zehra B & Nadeem U, *Can J Sci Ind Res*, 2 (2011) 164-170.
7 Mukesh T & Saikhedkar N K, *Res J Eng Sci*, 1 (2012) 32-37.
8 Suh K S, Lee Y S, Seo S H, Kim Y S & Choi E M, *Biol Trace Element Res*, 153 (2013) 428-436.
9 Sayin C, Gumus M & Canakci M, *Biomass Bioenergy*, 46 (2012) 435-446.
10 Xue J, Grift T E & Hansen A C, *Renew Sustain Energ Rev*, 15 (2011) 1098-1116.
11 Sadhik Basha J & Anand R B, *Int J Appl Eng Res*, 5 (2010) 697-708.
12 Beatrice C, Bertoli C, D'Alessio J, Del Giacomo N, Lazzaro M & Massoli P, *Combust Sci Technol*, 120 (1996) 335-355.
13 Song J, Cheenkachorn K, Wang J, Perez J, Boehman A L & Young P J, *Energy Fuel*, 16 (2002) 294-301.
14 Abu-Zaid M, *Heat Mass Transfer*, 40 (2004)737-741.
15 Yang Y B, Sharifi V N & Swithenbank J, *Fuel*, 83 (2004) 1553-1562.