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Full Length Article

Effects of nano-additives on pollutants emission and engine performance in a urea-SCR equipped diesel engine fueled with blended-biodiesel

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ABSTRACT

The present work submits an investigation about nano-additives influence upon performance and emission characteristics of a blended-biodiesel fueled diesel engine equipped with urea-SCR system. The base fuel utilized in this study was B20 blended biodiesel which contained of 20% waste frying oil biodiesel and 80% diesel fuel. Manganese oxide and cobalt oxide nanoparticles were used as nano-fuel additives with the mass fractions of 25 and 50 ppm in this study. Based on the experimental results, the brake specific fuel consumption and the brake thermal efficiency of nanoparticles blended fuel were considerably enhanced while the NO_x and CO emission were appreciably decreased compared to those of base fuel.

1. Introduction

Owing to recent energy crisis and diminishing fossil fuels reserves, the demand for alternative sources for diesels engines particularly biodiesel-based fuels is increasing [1]. The biodiesel fuel is easily available, non-toxic and eco-friendly [2]. On the other hand, because of high-oxygen content of biodiesels, they produce higher NO_x emission [3]. Hence, the major concern for diesel engines fed with biodiesel-based fuel is finding a way to decrease NO_x exhaust emission in order to meet the diesel emissions regulations.

In order to meet the stringent NO_x emissions norms, utilizing exhaust after-treatment systems is required for diesel engines fueled with biodiesel [4]. Among the $DeNO_x$ after-treatment systems, urea-SCR (selective catalytic reduction) is one of the most promising techniques which is able to decrease NO_x emissions sufficiently in diesel engines [5]. Urea solution is injected into the hot exhaust gas and then decomposes into ammonia. The main NO_x reduction reaction in SCR is as follows [5]:

$$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O \qquad (1)$$

Apart from the after-treatment method of NO_x reduction, fuel modification technology is another technique to obtain lower fuel consumption and NO_x emission from biodiesel combustion [4]. Nowadays, nanoparticles are considered as one of the best fuel additives to improve the fuel properties because of high surface area, shortened ignition delays and quick evaporation [6]. Many researches on influences of nano-additives upon engine performance and emissions characteristic of biodiesel-fueled diesel engines have been conducted. According to Ganesh and Gowrishankar, Magnalium (Al-Mg) and cobalt oxide nanoparticles addition to Jatropha biodiesel results in reduced exhaust emissions and improved engine performance in a single cylinder diesel engine [7]. Fangsuwannarak and Triratanasirichai showed that adding TiO_2 nanoparticles to Palm Oil biodiesel blended fuels leads to enhance the engine performance and reduce the exhaust emissions [8]. Ganesan and Elango studied the emission characteristics of Castor Oil biodiesel blend with the addition of MgO nanoparticles [9]. Karthikeyan et al. revealed that ZnO nanoparticles addition to PSW biodiesel results in improved engine performance and reduced exhaust emissions [10]. Syed Aalam and Saravanan reported the influence of Al_2O_3 and Fe_3O_4 nanoparticles as additive to the biodiesel blend fuel on fuel consumption and pollutants emissions [11]. Özgür et al. findings indicate that NO_x and CO emissions were decreased and engine performance values were slightly improved with the addition of MgO and SiO_2 nanoparticle to RME biodiesel [12]. According to Sharma et al., CNT and CeO_2 nanoparticles addition to biodiesel blended fuels results in lower HC, smoke and NO_x emissions and enhanced engine performance [13]. Chandrasekaran et al. investigated the effect of CuO nano-additives on engine performance and exhaust emissions from a diesel engine fueled with Mahua Oil biodiesel blends [14].

The present experimental investigation is aimed to study the influence of Mn_2O_3 and Co_3O_4 nanoparticles addition to blended-biodiesel fuels on the performance and emission characteristics of an internal combustion engine equipped with urea-SCR system.

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Table 1
Technical specifications of the engine.

Engine type	Inline, 4-cylinder, 4-stroke, water-cooled
Bore (mm)	104
Stroke (mm)	118
Displacement (cc)	4009
Compression ratio	17.9:1
Rated power (kW/rpm)	38/1500

2. Experimental setup and procedure

The experiments have been conducted on a 4-cylinder diesel engine mounted to an electrical generator. An adjustable load cell was connected to the generator in order to apply load on the engine. Fuel consumption was measured with the help of a digital scale and a stop watch, while a K-type thermocouple was utilized for exhaust gas temperature measurement. The exhaust emissions were recorded using a Testo 350 flue gas analyzer. The detailed specifications of the test engine are given in Table 1.

The test engine was equipped with an SCR system which involves the spraying of aqueous urea solution in the exhaust pipe. Urea dosing system includes a urea tank, a dosing pump and a spray nozzle. A burette and a stop watch were used in order to measure urea flow rate. Urea injection parameters have been set at the optimum design conditions obtained by Mehregan and Moghiman [15]. The schematic layout of the test setup is presented in Fig. 1.

The base fuel used in this investigation was B20 blended biodiesel which contained of 80% diesel fuel and 20% waste frying oil methyl ester biodiesel. The main properties of the fuels are mentioned in Table 2. Manganese oxide (Mn_2O_3) and cobalt oxide (Co_3O_4) nanoparticles were used as oxygenated additives to the base fuel in this study. The nano-additives were procured from US Research Nanomaterials, Inc. Table 3 shows the specifications of these nanoparticles. Also, the TEM images of Co_3O_4 and Mn_2O_3 nanoparticles are shown in Fig. 2. Nanoparticles were dispersed with the dosing levels of 25 and 50 ppm to the base fuel. In order to improve the stability of the fuel blends, the suspensions were kept in an ultrasonic bath for about half an hour.

In all experiments, the engine was started with neat diesel fuel at zero load condition and was allowed to warm up. Then, the fuel was switched to the test fuel and the experiments were conducted by varying the load at constant speed of 1500 rpm. After the engine reaches the steady-state condition, the measurement quantities have been recorded. After the completion of each test, the engine was again run with neat diesel fuel to prevent any deposits remaining in the fuel pipeline. The experiments were conducted at least three times to ensure the repeatability of the observed results and each recorded data was the mean value of three quantities. The uncertainties of the measured and calculated quantities are given in Table 4.

Table 2
Properties of Diesel and Biodiesel fuel.

Property	Fuel type	
	Diesel	Biodiesel
Density at 15 °C (kg/m^3)	818	880
Kinematic viscosity at 40 °C (mm^2/s)	2.65	4.79
Net calorific value (MJ/kg)	42.3	38.7
Cetane number	47.3	62
Carbon content (%)	86.4	77.1
Hydrogen content (%)	13.6	12.1
Oxygen content (%)	0	10.8

Table 3
Specifications of the Nanoparticles.

Nanoparticle	Symbol	Particle size (nm)	Purity (%)
Manganese oxide	Mn_2O_3	30	99.2
Cobalt oxide	Co_3O_4	10–30	99

3. Results and discussions

3.1. Brake specific fuel consumption

Fig. 3 presents the variation of brake specific fuel consumption (BSFC) with brake power for two different concentrations of both nanoparticles. The BSFC is defined as the ratio of fuel mass flow rate to engine output power [16]. It has been observed that by the addition of both nanoparticles to B20, the BSFC decreased efficiently. The addition of nanoparticles improves the properties of the base fuel and shortens the ignition delay which results in the reduction of the combustion temperature, and consequently lower NO_x formation [4,11]. Also, nano-contained blended fuels have higher heat value compared to the base fuel. Therefore, to maintain the same power output, less amount of fuel is consumed by the engine [7]. At each engine load condition, the BSFC reduces more with increasing the proportion of nanoparticle in the base fuel. This is attributed to higher heat value of the blended fuel with more dosing level of nano-additive.

Fig. 4 shows the percentage variation of BSFC of different blends with respect to base fuel at different load conditions. From this figure, it can be seen that cobalt oxide shows better improvement in BSFC than manganese oxide. This could be attributed to higher calorific value of

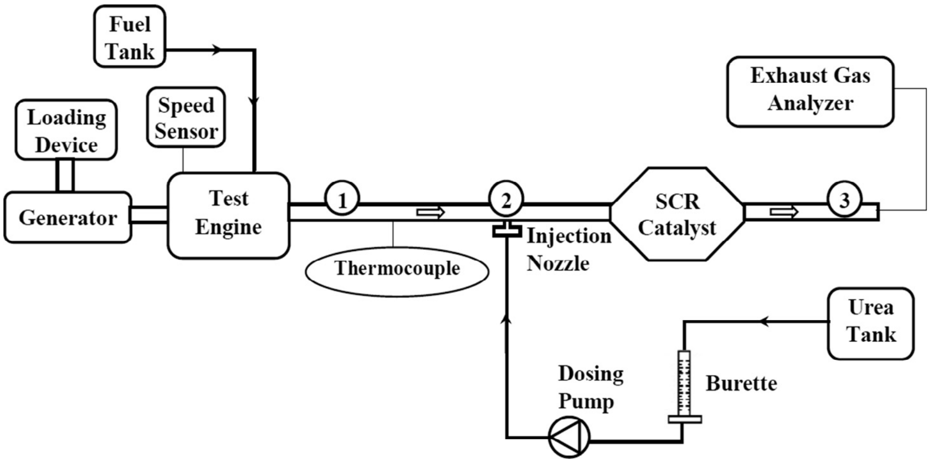

Fig. 1. Schematic diagram of the test setup. 1- Exhaust manifold; 2- Urea injection point; 3- Exhaust gas out.