Renewable Energy 80 (2015) 655–663

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Influence of alumina nanoparticles, ethanol and isopropanol blend as additive with diesel–soybean biodiesel blend fuel: Combustion, engine performance and emissions

T. Shaafi, R. Velraj*

Institute for Energy Studies, CEG, Anna University, Chennai, 600025, India

ARTICLE INFO

Article history:
Received 6 May 2014
Accepted 21 February 2015
Available online 16 March 2015

Keywords:
Diesel engine performance
Alternative fuels
Soybean biodiesel
Alumina nanoparticle
Emission characteristics

ABSTRACT

Experimental investigation was carried out to study the combustion, engine performance and emission characteristics of a single cylinder, naturally aspirated, air cooled, constant speed compression ignition engine, fuelled with two modified fuel blends, B20 (Diesel–soybean biodiesel) and diesel–soybean biodiesel–ethanol blends, with alumina as a nanoadditive (D80SBD15E4S1 + alumina), and the results are compared with those of neat diesel. The nanoadditive was mixed in the fuel blend along with a suitable surfactant by means of an ultrasonicator, to achieve stable suspension. The properties of B20, D80SBD15E4S1 + alumina fuel blend are changed due to the mixing of soybean biodiesel and the incorporation of the alumina nanoadditives. Some of the measured properties are compared with those of neat diesel, and presented. The cylinder pressure during the combustion and the heat release rate, are higher in the D80SBD15E4S1 + alumina fuel blend, compared to neat diesel. Further, the exhaust gas temperature is reduced in the case of the D80SBD15E4S1 + alumina fuel blend, which shows that higher temperature difference prevailing during the expansion stroke could be the major reason for the higher brake thermal efficiency in the case of D80SBD15E4S1 + alumina fuel blend. The presence of oxygen in the soybean biodiesel, and the better mixing capabilities of the nanoparticles, reduce the CO and UBHC appreciably, though there is a small increase in NO_x at full load condition.

1. Introduction

Diesel engines normally reveal higher thermal efficiency in automotive applications, due to their better fuel economy compared to gasoline engines. On the other hand, the combustion of diesel fuel emits more hazardous pollutants such as NO_x and particulate matter than gasoline engines. Polluted air leads to climate changes and affects plants, animals and human health. Moreover, conventional fossil fuels in the world are declining day by day, due to the growth of population and the subsequent energy utilization; and the stringent government emission standards have driven scientists and researchers to identify suitable renewable alternative fuels for diesel engines, for better performance and good emission control. Most of the researchers have contributed their efforts to reduce the emissions from the compression ignition engine (CI) in three ways 1) modifying the engine design 2) fuel modification 3) treatment of the exhaust gas.

The fuel modification method is widely accepted by many researchers to achieve the specific fuel properties, to improve the performance and emission control of the diesel engine. Xue et al. [1] reviewed the effect of biodiesel on engine performance and emissions, and concluded that, blends with a small portion of biodiesel are technically feasible as alternative fuels in a CI engine with no or minor modification to the engine. Hansen et al. [2] critically reviewed the ethanol-diesel fuel blend for engine performance, durability and emissions. Riberio et al. [3] critically reviewed the role of additives for diesel and biodiesel blended (ethanol or biodiesel) fuels. Gürü et al. [4] observed that the manganese additive had a stronger effect on the reduction of the fuel's freezing point, and also the exhaust emission of the fuel. The results showed that O_2 was reduced by 0.2%, and CO 14.3% and CO_2 was increased, but SO_2 was reduced, while the net efficiency was increased by 0.8%. Moreover, they concluded that the manganese additive improves the diesel fuel properties compared with other organic metals. The influence of a cerium additive on the kinetics of

* Corresponding author. Tel.: +91 4422357600; fax: +91 4422351991.
E-mail address: velrajr@gmail.com (R. Velraj).

http://dx.doi.org/10.1016/j.renene.2015.02.042
0960-1481/

oxidation and size distribution of ultrafine diesel particles, was studied by Jung et al. [5]. They observed that the addition of cerium to the diesel caused significant changes in number – weighted size distributions, light off temperature, and kinetics of oxidation.

The recent advances in nanoscience and nanotechnology paved the way to produce nanoscale energetic materials which have tremendous advantages over micron sized materials. Ignition delay and ignition temperatures are the critical parameters to characterize the performance and emissions of a diesel engine. Tyagi et al. [6] attempted to improve the ignition properties of diesel fuel by adding aluminium and aluminium oxide nanoparticles to diesel using the hot plate experiment. It was observed, that in all the cases the ignition probability for the diesel nanoparticle mixture was higher than that of pure diesel. Moreover, they concluded that, neither the change in the nanoparticle material nor the nanoparticle size influenced the ignition probability of the nanoparticle + diesel mixtures. The combustion characteristics of n-decane and ethanol considered as the base fluid with the addition of aluminium, boron, iron, and aluminium oxide were investigated by Refs. [7–9]. Based on the above, most of the researchers conducted their experiments with metal nanoadditives [10], metal oxide nanoadditives [11–14], magnetic nano fluid additives [15,16] and water diesel nanoparticle, emulsion [17–19], water diesel carbon nano tube emulsion [20], and nano organic additives [21,22] to the diesel fuel. Very few researchers worked, on the use of nanoadditives to biodiesel for the enhancement of the performance and emission characteristics. Sajith et al. [23] carried out an extensive investigation on a diesel engine fuelled with and without cerium oxide additives, to study the performance and emission characteristics. They found that the viscosity and volatility hold direct relations with the dosing level of 20–80 ppm. The emission levels of HC and NO_x are appreciably reduced with the inclusion of CeO_2. To reduce the NO_x and PM emission from the CI engines, emulsification techniques are adopted. Basha and Anand [24] investigated the performance and emissions of a diesel engine fuelled with biodiesel emulsion fuel incorporation of alumina nanoparticles in the mass fractions of 25, 50 and 100 ppm, with a higher concentration of water. They observed that the magnitude of NO_x, and smoke emission was 870 ppm and 49% for JBDS15W100A (83% jatropha biodiesel + 2% surfactant + 15% water + 100 ppm of alumina) fuel at full load. Further, the same team [25] studied the alumina – CNT blended with biodiesel fuel in the mass fractions of 25 and 50 ppm in a diesel engine. They observed a considerable enhancement in the brake thermal efficiency, and a marginal reduction in the harmful emissions. Further, they confirmed through their hot plate experiments that, a shorter ignition delay improved the heat transfer due to the enhanced surface area/volume ratio, and heat conduction properties. Metal based additives act as a combustion catalyst to 1) promote the combustion 2) reduce fuel consumption and 3) reduce emissions of hydrocarbon fuels. Kannan et al. [26] used ferric chloride as a fuel borne catalyst (FBC) to the waste cooking palm oil based biodiesel, to improve the properties of biodiesel. It was found from the experiments that, FBC added palm oil based biodiesel was a suitable alternative to diesel fuel. They observed a slight improvement in the brake specific fuel consumption, brake specific energy consumption and brake thermal efficiency for the FBC added biodiesel at optimized operating conditions. Fangsuwannarak [27] attempted a comparative study of palm biodiesel properties and engine performance with the addition of TiO_2 nanoparticles to palm biodiesel. The results showed that the nano TiO_2 additive of 0.1% by volume, gave the most effective performance, and also yielded better overall properties such as reduced kinematic viscosity, increased cetane number, increased lower heating value, increased flash point, but the quality of the fuel properties was decreased with the increase of the biodiesel blend. Moreover, the emission levels of CO, CO_2 and NO_x were appreciably reduced with the addition of the TiO_2 nanoparticles.

Selvan et al. [28] investigated the performance and emission characteristics of a CI engine using cerium oxide nanoparticles as an additive, in diesel and diesel-biodiesel-ethanol blends. They concluded that cerium oxide nanoparticle additive acts as an oxygen donating catalyst, and also provides oxygen for the oxidation of CO or absorbs oxygen for the reduction of NO_x. They revealed that the cerium oxide additive improved the complete combustion of the fuel, and reduced the exhaust emissions significantly. Cerium oxide nanoparticles exhibit high catalytic activity due to their high surface area per unit volume, which leads to improved fuel efficiency and reduction in emission.

The combustion behaviour of traditional liquid fuels with the addition of nanoscale energetic materials as fuel additives to enhance the performance and emissions in a diesel engine is an interesting concept. In the present work, the combustion, engine performance and emission characteristics of a single cylinder diesel engine fuelled with two modified fuel blends B20 (Diesel–soybean biodiesel), and diesel–soybean biodiesel–ethanol blends with alumina as nanoadditive (D80SBD15E4S1 + alumina), were tested and the results are compared with those of neat diesel.

2. Preparation of modified fuel blend and its properties

In the present study, two types of modified fuel blends are prepared and their performance are compared with neat diesel. The first blend consists of 80% diesel and 20% soybean biodiesel (B20). The second blend consists of a mixture of 80% diesel, 15% soybean biodiesel, 4% ethanol, and 1% isopropanol as a surfactant, and alumina nanoparticles of 100 mg/L are used to produce the modified D80SBD15E4S1 + alumina fuel blend. The commercially available Al_2O_3 nanoparticles of size less than 50 nm, procured from M/s Sigma Aldrich were used as additives in the present investigation. Its molecular weight, relative density, and surface area are 101, 96 g/mol, 4000 g/cm^3, >40 m^2/g respectively. Soybean biodiesel was procured from M/s Jatropha Oil Seed Development & Research, Hyderabad, India. By using the two-step method the modified fuel was prepared. First, 100 mg of alumina nanoparticles were mixed in ethanol (99.9% purity) and then, mixed with the diesel–soybean biodiesel blend. The phase separation is prevented by the addition of isopropanol as a surfactant in the above fuel blend. The fuel sample was transferred to the ultrasonicator to intensively disperse the particles and to reduce their agglomeration. The two step method works well for oxide nanoparticles [29–32]. Fig. 1 shows the TEM image of the Aluminium Oxide

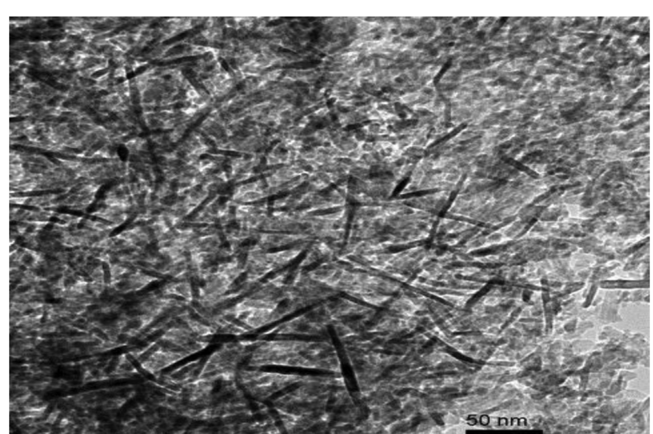

Fig. 1. TEM image of the Aluminium Oxide nanoparticle.