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The role of nano additives for biodiesel and diesel blended transportation fuels

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ABSTRACT

The energy crisis is due to two reasons, one is the rapid increase in worldwide population and the other is changing living style of human beings. The fossil fuel is also a major contributor to add the harmful pollutants into the atmosphere. Fuel modifications play a major role in increasing engine efficiency and reducing emissions. In the present investigation focused on fuel modifications in diesel engine. Initially the single cylinder diesel engine was operated with 20MEOM, 40MEOM, 60MEOM, 8MEOM and 100MEOM without additives with diesel at different loads at constant rated speed. From the experimental study proved that 20MEOM is the best fuel ratio compared to other blends. In second phase based upon first phase results the engine was operated 20MEOM blended fuel with adding 50 ppm copper oxide nano additives with diesel using solgel process. From the results, the brake thermal efficiency was 2.19% improved compared than 20MEOM blend without additive at full load condition. Emissions of HC, CO and smoke were considerably reduced. The present analysis reveals that the biofuel from mahua oil with nano additives is quite suitable as an alternate fuel for diesel engine.

Introduction

The transport sector plays a major role in the economic development of the country (Haiter Lenin et al., 2013). Diesel engines are used to power automobiles, locomotives, ships, and irrigation pumps and used widely to generate electric power (Ramreddy, 2014). Increase in population and living standards of human beings will lead to an energy crisis (Nandi, 2010). Due to the rapid increase in the demand for diesel and other petroleum products, India's dependence on oil import is expected to rise by 92% in the year of 2030 (Varathavijayan et al., 2013). Due to recent energy crises and dwindling reserves of crude oil the demand for alternate liquid fuels, particularly the biodiesel is increasing (Naramsetty et al., 2013). There are many advantages in using bio-diesel as an alternate liquid fuel such as easily availability, environment friendly, potential usage, biodegradable and contribution to sustainability (Demirbas, 2007).

Biodiesel can be extracted from various edible and non-edible vegetable oils. Many researchers have recommended non-edible oils to be a sustainable alternative for biodiesel production. They have identified several non-edible crops that can be

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used for biodiesel production, which include jatropa, karanji or pongamia, neem, jojoba, cottonseed, linseed, mahua, deccan hemp, kusum, orange and rubber seed (Ashraful et al., 2014; Hossain and Davies, 2010). In this study, mahua oil biodiesel is taken as an alternate fuel for diesel engine, since the chemical composition of mahua oil is almost similar to that of other non-edible oils (Heroor and Bharadwaj, 2013). Apart from that, many numbers of publications are available in jatropa, karanja and neem esters. Mahua oil is derived from the seeds of madhuca indica, a deciduous tree which can grow in semi-arid, tropical and sub-tropical areas (Mulimani et al., 2012). This oil is generally available in India and neighboring countries (Puhana et al., 2005). It has an approximate annual production possibility of 181 thousand metric tons in India (Shadangi and Mohanty, 2014). The drying and decortication yield is attained 70% of kernel on the weight of seed. The kernel of seed contains about 50% oil. The oil yield in an expeller is nearly 34–37% (Kapilan et al., 2009; Ghosal et al., 2009). When mahua oil is directly used as fuel in the engine it causes problems such as poor fuel atomization, incomplete combustion and carbon deposit formation, engine fouling and lubrication oil contamination, which is due to higher viscosity. In order to reduce the viscosity of mahua oil, several conversion methods such as blending of oils, micro emulsification, cracking/pyrolysis and transesterification are followed. Among these, transesterification is widely used for industrial biodiesel production. Mahua oil gives better yield than other transesterified non edible oil (Nandi, 2010). The usage of biodiesel in diesel engine gives some disadvantages such as, slight decrease in fuel economy on energy basis (about 10%), slightly greater density, less cloud and pour points and higher NO_X emission. These disadvantages are avoided by using techniques such as fuel additives, modified fuel, and hybrid fuel and that result in reduction in emissions and improvement in engine performance (Kadarohman et al., 2010). The addition of nano additives with biodiesel results in better fuel properties, to improve the combustion efficiency and to reduce harmful emissions (Senthilraja et al., 2010). And also addition of the additives to diesel fuel causes a decrease in particulate emissions, decrease in the oxidation temperature and increase in NO_X emission (Chlopek et al., 2005; Caton et al., 1990) Copper oxide (CuO) nano particles are insoluble in water, dissolve slowly in alcohol or ammonia solution and soluble in dilute acids and potassium cyanide solution. Under high temperature, copper oxide meets with hydrogen or carbon monoxide and can restore copper metal. Nano-copper oxide is a widely used material. It has been applied to the catalyst, superconducting materials, thermo-electric materials, sensing materials, glass, ceramics and other fields. In addition, the nano-copper oxide can be used as rocket propellant combustion catalyst.

Based on literature review and knowledge of authors no research was yet studied on CuO nano additive in mahua methyl ester blends as a fuel for diesel engine. The objective of the present study aimed to analysis the effect of CuO nano additive (50 ppm) in mahua biodiesel blend on the performance and emission characteristics of a direct injection single cylinder diesel engine.

Mahua biodiesel

Mahua biodiesel is prepared using transesterification process in this work. Transesterification is defined as the process of reacting a triglyceride (oil) with an alcohol (e.g., methanol or ethanol) in the presence of a catalyst, such as sodium hydroxide or potassium hydroxide, to chemically break the molecule of the oil into methyl or ethyl esters.

$$\begin{aligned}
&\text{Triglycerides} + \text{ROH} \rightleftharpoons \text{Diglycerides} + \text{R}^1\text{COOR} \\
&\text{Diglycerides} + \text{ROH} \rightleftharpoons \text{Monoglycerides} + \text{R}^2\text{COOR} \\
&\text{Monoglycerides} + \text{ROH} \rightleftharpoons \text{Glycerol} + \text{R}^3\text{COOR}
\end{aligned} \tag{1}$$

Eq. (1). Chemistry for production of methyl esters of bio-diesel.

The steps in the conversion process are triglycerides to diglycerides followed by the conversion of diglycerides to mono-glycerides and of monoglycerides to glycerol yielding one methyl ester molecule from each glycerides at each step of process and is shown in Eq. (1). The following steps were used to complete the transesterification process.

1. Methanol and NaOH were mixed in correct measured quantity.
2. Raw oil was heated up to a temperature of 60 °C.
3. Methanol and NaOH were mixed with mahua oil at constant temperature of 60 °C.
4. Mahua methyl ester and glycerine were separated in conical flask after 12 h interval time.
5. The free fatty acids and glycerine were removed from the flask.
6. Bubble washing was used to remove the remaining fatty acids and glycerine from the oil.
7. Esterified oil was collected from the flask.
8. Esterified oil was heated up to 100 °C, the water content was removed and pure biodiesel was obtained.

The mahua oil was purchased from the nearest forest areas of Hosur and Dharmapuri. The diesel was purchased from the open market. The raw mahua oil was not directly used in diesel engines. The transesterification process followed in this work is shown in Fig. 1. Table 1 presents the proportions of catalyst and alcohol (methanol) used for the preparation of biodiesel from one liter of mahua oil.