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Full Length Article

The influence of copper oxide nano particle added pongamia methyl ester biodiesel on the performance, combustion and emission of a diesel engine

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ABSTRACT

Biodiesel with small modification in its constituent has been often subjected to experimental analyses in diesel engine in order to substitute it as fuel for diesel engine. Environmental friendly aspects like biodegradability, renewability, easy and safety handling characteristics of biodiesel has been desired by all. But, the biodiesel has the negative side apart from its meritorious side. The performance and emission parameters of biodiesel like BSFC, BTE, smoke emission and NO_x emission has not meet out the emission norms prescribed by statutory bodies. Nano additives are found to be helpful in improving the fuel quality of improved performance and emission characteristics. In this study copper oxide (CuO) nano particles are mixed with pongamia biodiesel and subjected performance and emission analysis of engine operating characteristics in diesel engine. The experimental results provides a constructive result of 4.01% increase in BTE, a reduction of around 1.0% in BSFC and a reduction of around 12.8% in smoke emission and 9.8% reduction in NO_x emission for the blend B20CuO100.

1. Introduction

Energy plays vital role in the developmental activities of a country. Nature has gifted earth with various energy sources like wind energy, hydraulic energy, geothermal energy, tidal energy etc. Among the various energy sources, fossil fuel has been preferred by all due its high calorific value, safety for usage, easy to transport, safety to storage and easy adaptability with technological changes [1]. Fossil fuels are not environmental friendly and causes severe damage to the existence of the earth by polluting poisonous green house gases. It causes anxiety and distress among governing bodies of various countries, ecologist, socialists, scientist and even ordinary people.

Amidst these the demand for fossil fuel has not faded, instead increased in multiple folds due to the developmental activities in various sectors like industry, agricultural, mining, shipping, and infrastructures of a country combined with population growth [2,3]. In the fuel usage, road transport requires more fuel compare to other mode of transport. Road transport has been highly preferred by people because it well connects the nook and corner with ease of use. The transport vehicle pollutes the atmosphere. The Indian road transport is the one among the complex and largest one in the world which causes pollution.

As per the IEA report the fuel usage and demand of India dominate all other countries and will occupy first place. Until this year Japan is the leading nation in the world by consuming more fuel and it occupies the first place in fuel consumption. As per the IEA prediction India's fuel demand will be 6.2 million barrels a day, compared with 4.7 million of China. The Table 1 depicts the fossil fuel production and consumption in global level. As per the Indian position is considered there is an increasing demand of 3.8% of petroleum products compare to the last year consumption [4,5].

In the fossil fuel family, demand for diesel is high because diesel engines are used in all fields of engineering application like industry, power, agriculture, transport, mining, shipping and marine. The preference for diesel engine is due to the power output, existing technology, cost of operation and its reliability. Usage and expectation of diesel engine would be increased to around 10 percent in 2020 [6,7,38]. Atmospheric pollution by diesel engines causes various health disorders to human being and severe damage to the existence of the earth. To control the pollution and emission caused by the vehicles the statutory bodies has framed the stringent emission norms and takes vigorous steps like implementation of alternate fuels and fuel modification techniques to control emission.

Awareness about emission caused by fossil fuel causes for vigorous researches searching for a suitable new fuel or modified fuel which can be implemented in the engines with existing technology without causing additional cost. Biodiesel fulfill part of the expectation of the researchers as substitute fuel with reduced emission of Green House Gases (GHG) like CO and HC while implemented in exiting diesel

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Nomenclature

ASTM	American Society for Testing and Materials
BD	Base Diesel
BSFC	Brake Specific Fuel Consumption
BTE	Brake Thermal Efficiency
CI	Compression Ignition
CO	Carbon Monoxide
CO2	Carbon Dioxide
DI	Direct Injection
FFA	Free Fatty Acids
HC	Hydro Carbon
IEA	International Energy Agency
NO	Nitric Oxide
NO_X	Oxides of Nitrogen
PME	Pongamia Methyl Ester
SEM	Scanning Electron Microscope
XRD	X-ray Diffractometer

engine [8].

But, biodiesel has some limitations in implementing as substitute fuel in diesel engine. More fuel consumption due to its low calorific value with low brake thermal efficiency, increased NO_x and smoke emission are the constraints faced [9–11]. The performance and emission characteristics of biodiesel can be enhanced by nano additives incorporated with biodiesel. In this experimental work, CuO nano particle incorporated pongamia biodiesel has been subjected to various engine operating characteristics testing in four stroke single cylinder Kirloskar engine.

1.1. Nano particles as additives an overview

Various researches has been conducted by using nano particle impregnated biodiesel for the improved engine performance and operating characteristics by using different types of nano materials. The experimental results have revealed that there has been an improved emission characteristic for nano particle added biodiesel particular reduction in NO_x and smoke emission. The following section provides the literature reviews of different researchers.

Experimental study was conducted by Amit et al. [12] using cobalt oxide and iron oxide nano particle added jatropha biodiesel with mass fraction of 10, 20, 30, 40, 50 and 60 ppm with jatropha biodiesel. An ultrasonicator was used for homogeneous mixing of nano particle with biodiesel. The biodiesel with mixture of 40 ppm of nano particles provided enhanced thermal efficiency. An increase in thermal efficiency of around 2% was observed compared with pure diesel. Similarly, fuel economy of 0.010 kg/kWh had been experienced with nano particle mixed biodiesel compared to diesel.

Sadhik Basha et al. had examined the performance and emission characteristics of diesel engine by using alumina nano particles added jatropha biodiesel emulsion fuel having around 15% of water content. By using mechanical agitator, homogeneous mixture of jatropha biodiesel and nano particle was prepared in the presence of surfactant. Surfactant of Span80 sorbitane monooleate and Tween80 polyxyethylene sorbitane monooleate were used for preparing the emulsion. First, the surfactant mixture was prepared with the help of mechanical agitator by mixing Span80 and Tween80 with 2% by volume. The blend of surfactant and purified water of about 20% by volume has been agitated at different speed around 1750 rpm, 2250 rpm, 2750 rpm, and 3250 rpm for about half an hour at normal temperature of 28 °C. The prepared samples of biodiesel emulsion were in creamy yellow color. Stability period of the biodiesel emulsion has been conducted [13].

Table 1
Worldwide fossil fuel production and consumption.

Description	Million barrels per day			
Supply and Consumption	2014	2015	2016	2017
Non OPEC production	56.05	58.00	57.07	57.00
OPEC production	38.40	39.02	40.20	41.07
OPEC crude oil production	31.09	32.17	33.15	34.03
Total world production	**99.35**	**97.81**	**98.04**	**98.01**
OECD consumption	46.16	47.31	47.51	47.60
Non OECD consumption	47.69	48.63	49.80	51.07
Total world consumption	**93.85**	**95.04**	**96.33**	**97.67**

The use of nano particles highly enhanced the fuel characteristics of the biodiesel. The in-cylinder pressure, net heat release rate and ignition delay period had been reduced to great extent. BTE of nano particle added jatropha biodiesel had been increased with the reduction in NO_x and smoke emission. A reduction of around 32% and 27% of NO_x and smoke emission takes place respectively compared to diesel.

Poultry litter oil biodiesel was prepared with 20% biodiesel and 80% diesel by volume. Nano particle added emulsion of this fuel was prepared by using 30 mg of alumina nano particle per litre with the help of an ultrasonicator [14]. The ultrasonicator was used to dilute nano particles in base fluid to avoid the segregation of nano particles. Surfactants were added to reduce surface tension between liquid fuel and solid nano particles in order to normalize the nano particles. The authors had experimented that the B20 poultry litter oil biodiesel with and without alumina nano particles. With nano additive an increased BTE had been observed compared to diesel at full load. The in-cylinder pressure was found to be same for all operating conditions.

Experimental results had revealed that for the emulsion fuel, the emission of HC, CO decreases with an increase in NO_x as compared to diesel. The use of nano additives of alumina simultaneously improves the mechanical performance and the emission characteristics due to its catalytic effect on the fuel combustion process. A low volume of alumina in the range of 30 mg/l was suggested for the best engine performance with favorable emission characteristics [14].

The influence of nano particle added biodiesel on fuel properties and its effects on diesel engine operating characteristics were investigated by adding two dissimilar nano particle SiO_2 and MgO. Mixing of these nano particles with biodiesel was by volume basis of 25 ppm and 50 ppm to get different blends. The fuel properties, engine performance and exhaust emission characteristics of emulsified fuels were examined. The authors had observed the engine emission of NO_x and CO was decreased and engine performance had been enhanced by the addition of nano particle [15].

Prasad et al. had prepared karanja biodiesel emulsion by using 93% KBD, 5% distilled water, 2% of surfactants (Span80 and Tween80). Alumina nano particles were blended 50 ppm and 100 ppm doses with the KBD emulsion fuel. Experimental results had revealed that the influence of alumina nano particles added with KBD emulsion fuel had enhanced engine performance as well as emission characteristics [16].

Nagaraj Banapurmath et al. had studied the engine operating characteristics by using silver nano particles added with HOME. By using an ultrasonicator and a mechanical homogenizer silver nano particles had been mixed with HOME biodiesel at the mass fractions rate of 25 ppm and 50 ppm to get different blends. A notable increase in BTE with significant reduction in the emission was observed. Maximum BTE was obtained for HOME + 50SILVER with reduced emission compared to HOME + 25SILVER blends. The slots made on the piston crown had enhance the performance while using HOME + 50SILVER and for 6.5 mm slot on the combustion chamber in particular. HOME + 50SILVER + SLOTS showed lowered NO_x emission [17].

Experimental investigations were carried out by N. R. Banapurmath et al. on a single cylinder four stroke diesel engines fuelled with biodiesel nano particle blends to determine engine operating and emission