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Effect of operating parameters and antioxidant additives with biodiesels to improve the performance and reducing the emissions in a compression ignition engine – A review

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ABSTRACT

It is an overwhelming argument that the use of biodiesel in diesel engine causes slight decrease in performance and reduction in exhaust emissions but at the expense of oxides of nitrogen (NO_x) emission. In order to improve the performance without sacrificing the advantage in terms of exhaust emissions, it is essential to vary the engine operating parameters such as compression ratio (CR), injection pressure (IP) and injection timing (IT). Nowadays, treatment of biodiesel with antioxidant additive is a promising approach to reduce the NO_x emission because it reduces the hydrogen free radicals, which is responsible for prompt NO_x formation during combustion process. Hence, in the present review a detailed study has been carried out with the operating parameters and antioxidant additives used in biodiesel operated diesel engine so that its performance can be improved and exhaust emissions were reduced.

1. Introduction

1.1. General

In developing countries like India, transportation is vital for everyday activities and in the growth of economic condition. There are different modes of transportation such as road, water, air etc., in which fossil fuels are used abundantly. Besides transportation sector, the fossil fuels are used in power generation agricultural equipment and even in mine locomotives. In India, the consumption of petroleum derived fuel is about 30 million tons in the year 2015. During the last six decades, crude oil consumption rate in India have increased 16 times because of faster rate of vehicle population, industrial growth and agricultural development. Due to increasing usage of petroleum derived fuels, the cost of the crude oil is increased with the demand. India spends thousands of crores to import the crude oil for different application and it leads to lowering the Indian economy.

The biodiesel is produced from different sources and it may either from conventional or non-conventional sources. Some biodiesel blends can be directly used in engines without any modification, and some requires slight modifications like piston-cylinder coating, injection advance etc., to obtain the same performance to that of fossil fuel.

Further, in internal combustion (IC) engines there is an increase the exhaust emission such as carbon monoxide (CO), hydrocarbon (HC), NO_x, smoke etc. which cause damage to the environment and to the living medium present in the atmosphere. In order to meet out the present scenario, biodiesel usage will substitute the fossil fuel moderately.

1.2. Internal combustion engine

IC engine is a heat engine where the combustion of air fuel mixture occurs inside the combustion chamber that produces high temperature and high gas pressure. This gas pressure pushes the piston over a distance and transforms the chemical energy into thermal energy which is used for performing the mechanical work. The size and design of the engine varies according to the application and the requirements.

Several researches targeted to increase the efficiency of IC engines since it is used in many applications. In practice all the engines are compromised by their properties such as efficiency, weight, exhaust, noise, heat, power etc. If the efficiency of the engine is high, then it will give better fuel economy and thereby reduces fuel consumption and operating cost.

1.2.1. Compression ignition engine

Among the spark ignition (SI) and compression ignition (CI) engines, the CI engine plays a vital role since 80–90% of application of IC engines are used with CI engines. These engines are the major

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contributors to cause environmental impacts and threat to the living medium while emitting polluted gases. These are NO_x, CO, HC, CO_2, smoke and particulate matter and it may either directly or indirectly cause various issues on environment and living medium.

1.3. Biodiesel

Based on the various research reports, vegetable oils cannot be used directly in CI engine as they have more free fatty acids, phospholipids, sterols, water and other impurities. These contents are responsible for high viscosity, high flash point, lower volatility, higher cloud, and pour point. The higher viscosity of vegetable oil leads to low thermal efficiency, high smoke, and carbon residue. Many methods are adapted so for, like transesterification, pyrolysis and emulsification to reduce certain properties of biodiesel. Among these, transesterification seems to be a suitable process to produce biodiesel from vegetable oil and it enhances the fuel properties similar to diesel fuel.

As biodiesel contains more oxygen, emissions of CO, HC and smoke can be decreased to a large extent thereby making the environment greener. Despite these advantages, biodiesels have some disadvantages too, like higher viscosity and lower calorific value that have negative effects on performance, combustion and emission of the engine. The CI engines are designed to utilise the diesel as fuel. So they must be modified to an extent that they accept the biodiesel fuel. Researchers are keen to increase the engine operating parameters such as compression ratio, fuel injection timing, and fuel injection pressure to adapt the biodiesel in CI engine.

Nowadays, many researchers are conducting experiments using vegetable oil based biodiesel like, sunflower oil, peanut oil, soybean oil, rape seed oil, palm oil, cotton seed oil, line seed oil, corn oil, sesame oil, etc., in CI engines. These vegetable oils are edible and so, it may not be wise and practical.

Certain non-edible oils have been used in CI engines, and many non-edible oils are still to be used, such as neem oil, rubber seed oil, pongamia oil, nerium oil etc. These non-edible oils are available in plenty in India.

Biodiesel produced from non-edible oils have more advantages when used in CI engines, but on the performance point of view it is lower than that of diesel fuel due to its low calorific value and higher viscosity [2].

1.3.1. Sources of biodiesel

Typical raw materials of biodiesel are rapeseed oil, canola oil, soybean oil, sunflower oil and palm oil. Beef and sheep tallow and poultry oil from animal sources and cooking oil are also sources of raw materials. There are various other biodiesel sources: almond, andiroba (*Carapa guianensis*), babassu (*Orbignia* sp.), barley, camelina (*Camelina sativa*), coconut, copra, cumaru (*Dipteryx odorata*), *Cynara cardunculus*, fish oil, groundnut, *Jatropha curcas*, karanja (*Pongamia glabra*), laurel, *Lesquerella fendleri*, *Madhuca indica*, microalgae (*Chlorella vulgaris*), oat, piqui (*Caryocar* sp.), poppy seed, rice, rubber seed, sesame, sorghum, tobacco seed, and wheat. Various oils have been in use in different countries as raw materials for biodiesel production owing to its availability. Soybean oil is commonly used in United States and rapeseed oil is used in many European countries for biodiesel production, whereas, coconut oil and palm oils are used in Malaysiaand Indonesia for biodiesel production. In India and southeast Asia, the Jatropha tree (Jatropha cursas), Karanja (Pongamia pinnata), and Mahua (M. indica) is used as a significant fuel source [4].

1.3.2. Bio-diesel scenario in India

The India's energy demand is expected to grow at an annual rate of 4.8 per cent over the next couple of decades. Most of the energy requirements are currently satisfied by fossil fuels coal, petroleum based products and natural gas. Domestic production of crude oil can only fulfill 25–30% of national consumption and rest we are importing from other countries. In these circumstances biofuels are going to play an important role in meeting India's growing energy needs. Projected requirement of biofuel for blending under different scenario are given in Table 1.

Table 1
Projected demand for petrol and diesel and biofuel requirements.

Year	Petrol Demand (MT)	Diesel Demand (MT)	Biodiesel blending requirement (MT)		
			@5%	@10%	@20%
2006–07	10.07	52.32	2.62	5.23	10.46
2011–12	12.85	66.91	3.35	6.69	13.38
2016–17	16.40	83.58	4.18	8.36	16.72

India's demand for petroleum products is likely to rise from 97.7 million tonnes in 2001–02 to around 139.95 million tonnes in 2006-07, according to projections of the (Tenth Five-Year Plan). The plan document puts compound annual growth rate (CAGR) at 3.6% during the plan period. Domestic crude oil production is likely to rise marginally from 32.03 million tonnes in 2001–02 to 33.97 million tonnes by the end of the (10th plan period (2006–07)). India's self-sufficiency in oil has consistently declined from 60% in the 50 s to 30% currently. Same is expected to go down to 8% by 2020 (Bureau of Energy Efficiency, 2011). Final energy consumption is the actual energy demand at the user end. This is the difference between primary energy consumption and the losses that takes place in transport, transmission and distribution and refinement. The actual final energy consumption (past and projected) is given in Table 2. As per the Government of India's vision document 2020, cultivating 10 million hectares with Jatropha would generate 7.5 million tonnes of fuel a year, creating year round jobs for five million people.

1.3.3. Producer of biodiesel

Biodiesel is now being produced locally in India for use in stationary engines and large or slow engines like those in trains, trucks and tractors. Biodiesel-blends are being used to run state transport corporation buses in Karnataka. The University of Agriculture Sciences at Bangalore has identified many elite lines of Jatropha curcas and Millettia pinnata (Pongamia tree). Castor already a well-established crop in India with several very high yielding varieties in the market. For example, the government of Karnataka has distributed several million saplings of Pongamia to farmers for planting along borders of farmland and in waste lands. Large-scale plantations have been initiated in North-East India and Jharkhand by D1 Williamson Magor Bio Fuel Limited, a joint venture between D1 Oils of U.K. and Williamson Magor of India. The hilly areas of the North-East are ideal for growing hardy, low-maintenance plants [59].

1.3.4. Oxidation stability

The oxidation of fatty acid chain is a complex process proceeded by a variety of mechanisms. Oxidation of biodiesel is due to the unsaturation in fatty acid chain and presence of double bonds in the molecule

Table 2
Demands for commercial energy for fuel consumption.

Source	Units	1994-95	2001-02	2006-07	2011-12
Electricity	Billion Units	289.36	480.08	712.67	1067.88
Coal	Million Tonnes	76.67	109.01	134.99	173.47
Lignite	Million Tonnes	4.85	11.69	16.02	19.70
Natural Gas	Million Cubic Meters	9880	15,730	18,291	20,853
Oil Products	Million Tonnes	63.55	99.89	139.95	196.47