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FEASIBILITY AND FUTURE PROSPECTS OF BIODIESEL USE IN IC ENGINES - A REVIEW

R.P. Karsoliya, Research Scholar, Department of Mechanical Engineering, M. A. National Institute of Technology, Bhopal, India 462051;
R.K. Mandloi, Associate Professor, Department of Mechanical Engineering, M. A. National Institute of Technology, Bhopal, India 462051

Abstract

The economic stability of a country is primarily depends on its energy security, particularly for those countries that do not posses adequate fossil or nuclear resources. The variable nature of fossil fuels resources and with the steady increase in energy consumption has propelled research interest in alternative and renewable energy sources. As a sustainable, renewable and alternative fuel for compression ignition diesel engine, the research on biodiesel to study its effects on engine performances and emissions has been increased in the recent decade. Chemically, biodiesel is a monoalkyl ester of saturated and unsaturated long chain fatty acids obtained by the transesterification reaction between renewable feed stock like vegetable oils or animal fats and a monohydric alcohol in presence of a catalyst. The second generation feed stocks or non-edible vegetable oils can be considered as promising substitutions for traditional edible oils food crops for the production of biodiesel because of the tremendous demand for edible oils as food source and its costs are far expensive to be used as fuel. The aim of the present paper is to do a comprehensive review of engine performance and emissions using biodiesel derived from different non-edible oils and to compare that with the diesel.

Introduction

Energy is heart of everybody's quality of life. But the global population and the need for the energy increase hand-in-hand. The current fossil-fuel based energy system is not sustainable as it contributes substantially to climate change and depends heavily on imports from foreign countries. The burning of these fuels leads to emission of pollutant gases like CO2, HC, NOx, SOx. The reasons like rapidly increasing prices, increased environmental concern, uncertainties of petroleum availability and effect of green house gases. Industries have enhanced the search for alternative sources for petroleum-based fuel including diesel fuel [1]. Thus attention has been focussed on using alternative sources of energy such as biodiesel. The diesel engine is frequently used in transportation, power generation, industrial and agricultural applications, and in many more applications. The inventor of the diesel engine, Rudolph Diesel first tested peanut oil in his compression ignition engine in 1900 [2]. In spite of vegetable oils performance in diesel engine the concerns that their higher costs as compared to petroleum fuel would prevent their prevalent uses. Vegetable oils create engine problems when used as diesel fuel especially indirect-injection engines. The major drawback of vegetable oils is their high viscosity which causes trumpet formation on the injectors and coking resulting in poor atomization and ultimately leads to operational problems [3].

Transesterification is one of the most common solutions to reduce viscosity of vegetable oil which yields mono alkyl esters of long chain fatty acids or fatty acid alkyl ester (FAAE). In 1938 this idea of transesterification was originated that the glycerine in vegetable oils is likely to cause excess carbon deposit on the engine part and has no calorific value. Therefore it should be eliminated from the vegetable oils and the engine should run on the residue fatty acid. The residue fatty acid is known as “biodiesel”. The fatty acid part or biodiesel is ten times less viscous than vegetable oil. Biodiesel is biodegradable, renewable, environmental friendly, non-toxic, eco friendly and readily available fuel [3].

Selection of proper feedstock for production of biodiesel is very important since the input cost is a major contributor to the production cost and affects the yield of the final product. There are two different generation of potential feed stocks for biodiesel production. One is the edible vegetable oils and the second are the non edible vegetable oils. In the production of biodiesel abroad more than ninety five percent of feedstocks come from edible oils and these oils are much suitable to be used as diesel fuel substitute. Hence, the use of these feedstocks could not be possible in India. Therefore, non-edible vegetable oils or the second generation feedstocks have become more attractive for biodiesel production. These feed stocks are very promising for the sustainable production of biodiesel. Moreover, microalgae with high oil content have the potential to produce an oil yield that is upto twenty five times higher than the yield of traditional biodiesel crops, such as palm oil. [4]

This study concentrates on assessing the viability of using biodiesel as alternative fuels in the existing compression ignition engines. In this review, the results of some of the research works of vegetable oils are compared, summarized and added the research short comes to be incorporated in future work.

The Biodiesel production process

The key to effectively preparing for the biodiesel process is to make sure the feedstocks have been sufficiently filtered by removing all contaminants and water. Upon filtration the feedstocks are fed to the transesterification process. The catalyst usually sodium hydroxide or potassium hydroxide is dissolved in alcohol usually methanol and then blend with the pretreated oil. The co-products of this reaction are biodiesel and glycerine as shown in figure 1.

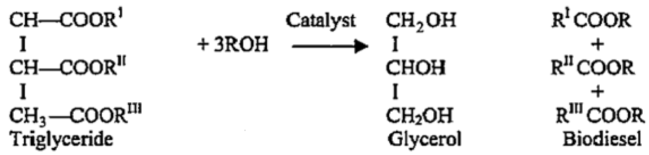

Figure 1. The transesterification reaction (R^{I}, R^{II} and R^{III} are long-chain hydrocarbons which may be the same or different with R = CH_3/C_2H_5).

The overall transesterification reaction [5] is given by three consecutive and reversible equations as below:

$$\text{Triglyceride} + \text{ROH} \overset{\text{catalyst}}{\Longleftrightarrow} \text{Diglyceride} + \text{R}^{\text{I}}\text{COOR}$$

$$\text{Diglyceride} + \text{ROH} \overset{\text{catalyst}}{\Longleftrightarrow} \text{Monoglyceride} + \text{R}^{\text{II}}\text{COOR}$$

$$\text{Monoglyceride} + \text{ROH} \overset{\text{catalyst}}{\Longleftrightarrow} \text{Glycerol} + \text{R}^{\text{III}}\text{COOR}$$

The first step is the conversion of triglycerides to diglycerides, followed by the conversion of diglycerides to monoglycerides, and of monoglycerides to glycerol, yielding one methyl ester molecule per mole of glyceride at each step.

Once separated from the glycerin, the biodiesel goes through a purification process, removing all remaining alcohol and catalyst. It is then dried and stored. To guarantee the biodiesel is without color, odor and sulfur, an additional distillation process may be implemented. Biodiesel can be used as pure fuel namely B100 or used in blending with neat diesel fuel. Biodiesel blends are denoted as "BXX" with "XX" representing the percentage of biodiesel contained in the blend e.g., B80 is 80% of biodiesel, 20% of petroleum diesel. Similarly, B20 contains 20% biodiesel. Blends of 20% biodiesel and lower can be used in diesel engine with no or only minor modifications. [4, 5]

Properties of biodiesel

Some of the biodiesel fuels properties [6-22] are compared in Table 1.The characteristics of biodiesel are close to petroleum diesel, and, therefore, biodiesel becomes a strong candidate to replace the petroleum diesel. The conversion of vegetable oil into biodiesel through the transesterification process reduces the molecular weight and the viscosity of vegetable oils and increases the volatility marginally.

Engine performances and emissions

To evaluate the performance of diesel engine using biodiesel and its blends the following operating parameters have to decide.

A. Brake Mean Effective Pressure (BMEP)

Table 1. The Poperties of Bodiesel

Properties	Diesel	Biodiesel				
		Jatropha curcas L.	Karanja	Castor	Mahua	Cottonseed
density (g/cc)	0.83	0.88	0.88	0.91	0.88	0.85
kinematic viscosity at 40 C (cst)	4	4.12	9.5	10.4	5.58	6
Flash point (˚C)	44	162	187	149	170	200
cloud point (˚C)	4	-4	-2	-	-3	-2
pour point (˚C)	-6	-8	-6	-	-18	-4
Calorific value (MJ/kg)	42.5	39.6	36.6	46.2	42	41.6
Cetane number	47	57	48	42	-	52

It is a very effective yardstick for comparing the performance of different fuels. It is defined as the average or mean pressure through one complete operating cycle which, if imposed on the pistons uniformly, would produce the measured or brake power output. BMEP is independent of the RPM and size of the engine. BMEP is purely theoretical and has nothing to do with actual cylinder pressures. It is simply a tool to evaluate the efficiency of a given engine at producing torque from a given displacement.

B. Mechanical Efficiency (η_m)

Part of the indicated work per cycle is used to expel exhaust gases, induct fresh air, and also overcome the friction of the bearings, pistons, and other mechanical parts of the engine. The mechanical efficiency is the measure of the ability of the engine to overcome the frictional power loss and can be defined as the ratio of BP to IP.

$$\eta_m = \frac{BP}{IP} \quad (4)$$

C. Brake Specific Fuel Consumption (BSFC)

The BSFC defined as the fuel flow rate per unit of power output. It is desirable to obtain a lower value of BSFC that is the engine will use less fuel to produce the same amount of work.

D. Brake Thermal Efficiency (BTE)

It is the ratio of the thermal energy in the fuel to the energy delivered by the engine at the crankshaft. It greatly depends on the manner in which the energy is converted as the efficiency is normalized respect to the fuel heating value. It can be expressed by:

$$\text{BTE } (\eta_b) = BP/(m_f \text{ x NCV}) \quad (5)$$

where, m_f = fuel consumption and NCV = net calorific value

E. Comparable Effect on Operating Parameters

The above defined parameters are determined by various researchers by performing experiments on the diesel engine with biodiesel produced by different vegetable oils. Due to less calorific value and inefficient combustion the engine power decreased with the utilisation of biodiesel [19]. However properties like higher density which results in injection of increased mass of fuel and higher viscosity which reduces the leakage of fuel are favourable to compensate power loss due to less calorific value of biodiesel [14]. It was reported that there was no significant difference in engine power between biodiesel and diesel [20].

It has also been reported there is an increase in fuel consumption in case of biodiesel compared to diesel [6]. This is attributed due to combined effects of the higher fuel density, viscosity and low heating value of biodiesel. The higher densities of biodiesel resulted in higher values for BSFC because it led to more discharge of fuel for the same displacement of the plunger in the fuel injection pump.

The BTE obtained from biodiesel was lesser than that of diesel which is attributed to poor air fuel mixing, poor spray characteristics, higher volatility, higher viscosity and lower calorific value [6, 7]. Due to smaller ignition delay of biodiesel causes increases in the compression work as well as heat loss that also leads to reduction in the efficiency of the engine.

F. Effect on Exhaust Emissions

Biodiesel has shown a lot of promise in terms of lower harmful emissions compared to diesel. Canakci [21] and Nabi et al. [22] found 18.4% and 4% reductions in CO emissions, respectively with B100 due to oxygen content of biodiesel and also due to lower carbon to hydrogen ratio of biodiesel. The complete combustion of the fuel with biodiesel is possible because biodiesel has oxygen contain in their molecule [18].

There is contradiction regarding emission of NOx in the literature. Some of the literature reported higher NOx emission with biodiesel. The major causes for biodiesel's increased NOx emissions content of oxygen in biodiesel. Approximately 10% increase in NOx emission was reported by Rao et al. [7] with 30% biodiesel mixtures.

There are also some evidences of less emission of NOx. Kalligeros et al. [23] reported 38.4% reduction of NOx emissions, which is due to lower flash point and higher cetane number of biodiesel.

PM (particulate matter) which is composed mainly of drysoot, sulphate and soluble organic fraction [23] were generally reduced with the use of biodiesel as compare to diesel. Shorter ignition delay due to higher cetane number of biodiesel and longer combustion duration results in low particulate emissions [18]. The smoke emission is also lowered due to low carbon to hydrogen ratio [24].

It has also been reported the significant reduction in hydro carbons (HC) emission with biodiesel. Kalligeros et al. [25] reported that the addition of methyl esters contributed to a faster evaporation and more stable combustion, and hence, a decrease in HC in comparison to diesel. At higher loads, HC emission increases due to higher fumigation rate and non-availability of oxygen relative to diesel [26].

CO_2 emissions of biodiesel are higher than that of diesel fuel due to the presence of oxygen in biodiesel and relatively lower content of carbon in biodiesel for the same volume of fuel consumed [6].

The analysis and summary of this work is helpful for researchers and engine manufacturers to optimize and readjust biodiesel engine and to develop the further related research for its relevant systems. It will also helpful for governments to design new energy policies relating to the use of biodiesel in the light of environmental costs and for private users to understand profits for using biodiesel, and to enhance awareness of environmental protection.

As per the author's point of view, it has been observed that no literature is available for the effect on operating parameters and emissions performance of biodiesel with the engine operating temperature related to ambient atmospheric temperatures. The authors are in strong opinion to evaluate the research on engine operating temperature with biodiesel with its blends as this would have definite impact on engine performance, especially specific fuel consumption, power out put and as well as emissions.

Conclusions

Clearly, biodiesel is one of the environmentally responsible alternatives to petroleum-based gasoline and diesel. Still tremendous scope of research is there to optimize the operating temperature based fuel economy and emissions. The agricultural industry can be expanded through the use of biodiesel in automotives. The devastating effects of corporate agribusiness practices would be tempered and the small marginal farmers would have good opportunity for their better survival and return back to the community with lavishness. In general the food versus fuel conflict does not arise if non-edible oils are used as biodiesel.

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Biographies

KARSOLIYA R.P. .is research scholar at M. A. National Institute of Technology, M.A.N.I.T., (An Institute of National Importance, under Ministry of H.R.D., Govt. of India). R.P. Karsoliya may be reached at
manitkarsoliya@gmail.com

MANDLOI R.K. received the B. Tech. degree in 1982, then M. Tech. and Ph.D. (Automobile Engineering) from (MACT) now M.A.N.I.T. He joined this institute in 1985 as JRF, & served in Problem Oriented Research Laboratory (PORL), since 1990 worked on different positions in Mechanical Engineering Department. In 2006 became Associate Professor & Head, Central Workshop, Mechanical Engineering Department, MANIT, Bhopal. Dr. R. K. Mandloi may be reached at
profrkmandloi@yahoo.com