IJARI

International Journal of Advance Research and Innovation
Vol. 2(4), Oct-Dec 2014, pp. 77-82
Doi: 10.51976/ijari.241412
www.gla.ac.in/journals/ijari

Article Info

Received: 10 Oct 2014 | Revised Submission: 25 Oct 2014 | Accepted: 20 Nov 2014 | Available Online: 15 Dec 2014

Optimization of Production and Performance of Biodiesel Through Optimization Techniques: A Review

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ABSTRACT

Biodiesel is recently gaining importance as a substitute for petroleum based diesel mainly due to environmental considerations and depletion of vital resources like petroleum and coal. According to Indian petro fuel consumption scenario, the demand for petroleum diesel is increasing day by day hence there is a need to find out an appropriate solution may be biodiesel but the cost of biodiesel produced from vegetable oil through transesterification is higher than fossil fuel, because of high raw material cost. To minimize the biodiesel cost, in recent days, in most cases, NaOH is used as alkaline catalyst, because of its low cost and higher reaction rate. In this review the important process variables for esterification such as concentration of acid catalyst, alcohol/oil ratio, reaction time, temperature, and % of excess alcohol are optimized. The results are also verified with Ganetic Algoritham (GA) method and Taguchi method. Also summarized the research works in optimization of C. I. engineperformance and operating parameters for biodiesel fuel using optimization techniques.

Keywords: *Biodiesel; Engine Performance; Transesterification; Optimization Techniques*.

1.0 Introduction

In recent times there has been an increase in the efforts to reduce the reliance on petroleum fuel for energy generation and transportation and attention is being focused on alternate fuels. Among the alternative fuel, biodiesel and diesohol have receive the much attention for diesel engine due to their advantages as the renewable, domestically produced energy resources and they are environment friendly because there is substantial reduction of unburnt hydrocarbon (UHC), Carbon monooxide (CO) and particulate matter (PM) when it is used in conventional diesel engine. Vegetable oils have been converted to biodiesel via a chemical process, known as transesterification process [1], Resulting fuel is biodiesel, a biodegradable and nontoxic renewable fuel. Furthermore, biodiesels have reduced viscosity, and improved volatility when compared to ordinary vegetable oil. Biodiesel can be produced either from edible or from non- edible oils. Most of the edible oils are produced from the crop land. The idea of using vegetable oil as fuel for diesel engines is not a new one. Rudolph Diesel used peanut oil as fuel in his engine at Paris Exposition of 1900. Inspite of the technical feasibility, vegetable oil as fuel could not get acceptance, as it was more expensive than petroleum fuels. Later various factors as stated earlier, renewed the interests of researchers in using vegetable oil as substitute fuel for diesel engines. In recent years, systematic efforts have been made by several researchers to use vegetable oils of Sunflower, Peanut, Soyabean, Rapeseed, Olive, Cottonseed,

Jatropha, Pongamia, Rubber seed, Jojoba etc as alternate fuel for diesel. Many types of vegetable oils are edible in nature. Continuous use of them causes shortage of food supply and proves far expensive to be used as fuel at present [2]. More than 350 oil-bearing crops have been identified, of which only soyabean, palm, sunflower, safflower, cottonseed, rapeseed, and peanut oils are considered potential alternative fuels for diesel engines. Vegetable-oil fuels have not been acceptable because they are more expensive than petroleum fuels. However with recent increase in petroleum prices and uncertainties surrounding in the petroleum availability. Soybeans are commonly used in the United States, as food products, Soyabean oil turned out to be a primary source for biodiesel in that country. In Malaysia and Indonesia, palm oil is the source of biodiesel. In Europe, rapeseed is the source

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of biodiesel. In India and Southeast Asia, jatropha tree is the source of biodiesel. Major exporters of vegetable oil are Malaysia, Argentina, Indonesia, Philippines, and Brazil. Major importers of vegetable oils are China, Pakistan, Italy, and the United Kingdom. A few countries such as the Netherlands, Germany, the United States, and Singapore are both major exporters as well as importers of vegetable oils. The non-edible oils such as jatropha, microalgae, neem, karanja, rubber seed, mahua, silk cotton tree etc. are easily available in developing countries and are very economical compared to edible oil.

2.0 Production of Biodiesel from vegetable oil

Biodiesel can be produced by esterification followed by transesterification. The oils and fats are filtered and pre-processed to remove water and contaminants. If, free fatty acids are present, they can be removed or transformed into biodiesel using special pretreatment technologies. The pre-treated oils and fats are then mixed with an alcohol (usually methanol) and a catalyst (usually sodium methoxide). The oil molecules (triglycerides) are broken apart and reformed into esters and glycerol, which are thenseparated from each other and purified. The edible oils like soybean, sunflower, mustard, palm, cotton seeds, whose acid values are less than 3.0 are transesterified with methanol in the presence of sodium methoxide as catalyst. Non-edible oil like, Mahua, karanja and jatropha oils having acid values more than 3.0 are undergoes esterification followed by transesterification. The methyl esters produced by these methods are analyzed to ascertain their suitability as diesel fuels.

3.0 Chemistry of Esterification and Transesterification

Esterification: In order to eliminate saponification reaction (formation of soap when FFA reacts with homogenous base catalyst) vegetable oil can be pretreated with acid catalyst, which esterifies free fatty acid to form esters of free fatty acid (biodiesel). This reaction is very much useful when raw material contains high percentage of free fatty acid (esterification of free fatty acid to form free acid esters). But this reaction is slower than base catalyzed transesterification reaction. The esterification reaction is given as shown in

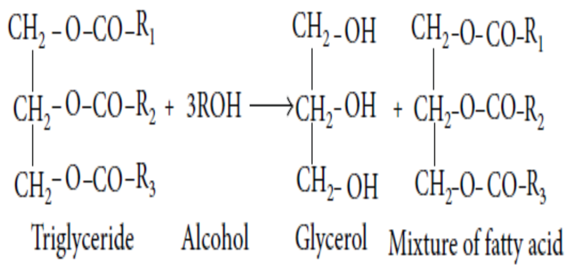
Fig 1: Esterification Reaction

$$\underset{\text{FFA}}{R_1\text{-COOH}} + \underset{\text{(alcohol)}}{\text{ROH}} \longrightarrow \underset{\text{Fatty acid ester}}{R\text{-O-CO-}R_1} + \underset{\text{(water)}}{H_2O}$$

Esterification is the reaction of an acid with an alcohol in the presence of a catalyst to form an ester. The equation is expressed generally as: Generally, acid catalyst like sulfuric acid is employed. Esterification is a reversible reaction. Thus water produced must be removed to drive the reaction to the right to obtain a higher ester yield.

Transesterification: On the other hand is the displacement of the alcohol from anester by another alcohol in a process similar to hydrolysis, except that an alcohol is used instead of water. This reaction cleavage of an ester by an alcohol is more specifically called alcoholysis and is represented by the general equation:

Fig 2: Transesterification Reaction



In this case, a new ester is formed. Generally alkaline catalysts such as, Sodium hydroxide and Potassium hydroxide can also be used as catalysts. Transesterification is a general term. More specifically, if methanol is used, the reaction is termed methonolysis. Methanol is generally used because it is cheap, however other alcohols can also be used.

Although the equation reflects the overall reaction, but the reaction usually consists of a series of consecutive reversible steps. For transesterification reaction a large number of potentially useful catalysts have been investigated as a means to enhance the reaction rate. Without added catalysts some degree of rearrangement can be obtained but only under extreme conditions of temperature and time, leading to undesirable effects such as isomerization, polymerization and decomposition. Apart from the generally preferred acid and alkaline catalysts, Sodium Methoxide and Alcolates, have been claimed to catalyze transesterification reactions. This catalyst has the advantages of reducing the reaction time and temperature, used in small quantity without darkening the color of the oil. Transesterification of vegetable oils using methanol and alkaline catalyst is the most commonly used processes for manufacture of methyl esters.

4.0 Process VariablesAffecting the Production of Biodiesel

The most important variables which influence the transesterification reaction are: reaction temperature, ratio of alcohol to vegetable oil, catalyst mixing intensity and purity of reactants.

4.1. Reaction temperature

The literature has revealed that the rate of reaction is strongly influenced by the reaction temperature. However the reaction is conducted close to the boiling point of methanol (60 – 70 0C) at atmospheric pressure for a given time. Such mild reactionconditions require the removal of free fatty acids from the oil by refining or preesterification. Therefore degummed and de acidified oil is used as feedstock [12].

Pretreatment is not required if the reaction is carried out under high pressure (9000 kPa) and high temperature (2400C), where simultaneous esterification and transesterification take place with maximum yield obtained at temperatures ranging from 60 – 80 0C at a molar ratio of 6:1 [3-5].

4.2. Ratio of alcohol to oil

Another important variable is molar ratio of alcohol to vegetable oil. As indicated earlier, the transesterification reaction requires 3 mol of alcohol per mole of triglyceride to give 3 mols of fatty esters and 1 mol of glycerol. In order to shift the reaction to the right, it is necessary to either use excess alcohol or remove one of the products from the reaction mixture.

The second option is usually preferred for the reaction to proceed to completion. The reaction rate was found to be highest when 100% excess methanol was used. A molar ratio of 6:1 is normally used in industrial processes to obtain methyl ester yields higher i.e. 98% (w/w)[3].

4.3. Catalysts

Sodium alkoxides are the most efficient catalysts, although KOH and NaOH can also be used. Transmethylation occurs in the presence of both alkaline and acidic catalysts [5]. Being less corrosive to industrial equipment, alkaline catalysts are preferred in industrial processes. A concentration in the range of 0.5 – 1% (w/w) has been found to yield 94 – 99% conversion to vegetable oil esters [4], and further increase in catalyst concentration does not affect the conversion but adds extra cost, as the catalyst needs to be removed from the reaction mixture after completion of the reaction.

4.4. Mixing intensity

It has been observed that during the transesterification reaction, the reactants initially form a two-phase liquid system. The mixing effect has been found to play a significant role in the slow rate of reaction. As phase separation ceases, mixing becomes insignificant. The effect of mixing on kinetics of the transesterification process forms the basis for process scale-up and design.

4.5. Purity of reactants

Impurities in the oil affect the conversion level considerably. It is reported that about 65 – 84% conversion into esters using crude vegetable oils has been obtained as compared to 94 – 97% yields refined oil under the same reaction conditions [3]. The freefatty acids in the crude oils have been found to interfere with the catalyst. This problem can be solved if the reaction is carried out under high temperature and pressure conditions.The important variables which influence the performance of engine, injection time, injection pressure and heat release rate on engine performance.

5.0 Optimization Techniques

Some of the researcher had work on the optimization of diesel engine performance and operating parameters using different technique as suitable software [6], as like Taguchi method, Matlab, Artificial Neural Network (ANN).

These techniques are computationally efficient for optimization requiring hundreds of function evaluations; this saves cost and time in developing new models and methodologies for overall engine management [7]. For analyzing complex problems of emission analysis of biodiesels and their blends, artificial neural network is suitable, adaptable and flexible computing tool that can be used for diagnostic purposes. There by, time consuming, tedious and costly experiments can be avoided. An overview of applications of artificial neural networks (ANN) in the field of engine development described two back-propagation learning algorithms to predict the torque, power, specific fuel consumption, and smoke emission of diesel engine using different injection pressure and engine speed is given by Garg et al. [8]. Balajiganesh et al. [9] worked on the Optimization of Compression Ignition Engines through advanced artificial neural network using Mat lab.

The engine is operated by using diesel and sunflower oil blends and calculate optimized performance as like indicated power, brake power, break mean effective pressure, indicated mean effective pressure and specific fuel consumption. Also Mudgal et al. [10] worked on the Prediction of Emissions from Biodiesel Fueled Transit Buses Using Artificial Neural Networks.

Shivakumar et al. [11] had worked on the Experimental investigation on the Performance parameters and Exhaust emissions from the four strokes C.I. engine operated on honge methyl ester. Back-propagation algorithm was used to train the network. In this work they selected the inputs for the ANN are blend percentage (B), load percentage (W), and the compression ratio (CR). The output parameters from the ANN are Brake thermal efficiency (BTE), Brake specific energy consumption, (BSEC), Exhaust gas Temperature and the emissions which include Oxides of nitrogen (NOx), Smoke (SN), Unburnt Hydrocarbon (UBHC), and Carbon Monoxide (CO).

Lastly he had investigated the ANN results; showed good correlation between the ANN predicted values and the desired values for various engine performance values and the exhaust emissions. Some researcher had worked on the taguchi approach for the optimization of performance and operating parameters of the diesel engine. For example, Sivarama krishnan and Ravikumar [13] worked on the optimization of the direct injection (DI) single cylinder diesel engine with respect to brake power, fuel economy and emissions through experimental investigations and DOE methods. In the experimental investigations conducted on a single cylinder DI diesel engine using Eucalyptus oil mixed with diesel fuel. Taguchi method of optimization predicted optimum level of parameters within 9 trials and the 40Eu blend found working satisfactorily at optimum setting, also in this work he had investigated the NOx emission found while working with 40Eu blend at optimum level.

Here for optimization purpose he had use the orthogonal array with four columns and nine rows were used to design Taguchi experiment. Also lastly he had investigate the 50% smoke reduction was achieved with 40Eu operation [14]. The purpose of analysis of variance (ANOVA) is to investigate the percentage contribution of variance over the response parameter [14].

Lastly he had investigated the Taguchi method of optimization predicted optimum level of parameters within working satisfactorily at optimum setting. Some researchers states that the taguchi is most effective method for optimization of diesel engine performance parameters. For example, [14, 15] in this work consist an experimental study that involves an application of the Taguchi method and grey relational analysis to determine the optimum factor level to obtain optimum multiple performance characteristics of a diesel engine run with different low-percentage thumba biodiesel-diesel blends [16].

Taguchi method of optimization predicted optimum level of parameters within 9 trials and the 40 Turpentine blend found working satisfactorily at optimum setting. Lastly he proved that the blending of turpentine with diesel fuel up to 40% increases the engine Performance without much more effecton emission.

6.0 Conclusion

Biodiesel produced from vegetable oil (edible and non edible oil) renewable sources, it is a more sustainable source of energy and it will be play an increasingly significant role in providing the energy requirements for transportation. The Properties of biodiesel closely related to diesel fuel.

The use of biodiesel will lead to loss in engine power mainly due to the reduction in heating value of biodiesel compared to diesel fuel. Increase in biodiesel fuel consumption, due to low heating value and high density and viscosity of biodiesel, has been found. PM emissions HC, CO emissions for biodiesel are significantly reduced, compared with diesel fuel.

But NOx emissions may increases when using the biodiesel, this increase is mainly due to higher oxygen content for biodiesel. From the literature survey it can be concluded that the blends of biodiesel with small Content by volume could replace diesel in order to help in controlling air pollution and improving engine performance of power and economy of engine when using biodiesel blending with diesel fuel. From the literature it may concluded that the Optimization of C.I. engine performance and operating parameters through different software is most suitable technique. Also it is more accurate technique and less time consuming as compaired to experimental method. Use of Artificial Neural networks for optimizing the C.I Engine parameters is most suitable technique. Therefore ANN will be a very good tool to optimize engines parameters in the future. Also the taguchi method can be effectively used for the investigation of multiple performance characteristics of a diesel engine.

Reference

[1] Jon Van Gerpen, Biodiesel processing and production, ElsevierFuel Processing Technology 86 (2005) 1097– 1107

[2] S. Jaichandar, K. Annamalai, The status of Biodiesel as an Alternative Fuel for diesel engine, Journal of Sustainable Energy and Environment, 2, 2011, 71-75

[3] C. Carraretto, A. Macor, A. Mirandola, A. Stoppato, S. Tonon, Biodiesel as alternative fuel : Experimental analysis and energetic evaluations, Energy, 29, 2004, 2195-2211

[4] A. Abraham, Artificial Neural Networks, John Wiley & Sons, 2005

[5] Neural Networks: A Comprehensive Foundation (2nd Edition)

[6] M. Venkatraman, G. Devaradjane, Computer Modeling of a CI Engine for Optimization of Operating Parameters Such asCompression Ratio, Injection Timing and Injection Pressure for Better Performance and Emission Using Diesel -Diesel BiodieselBlends, American Journal of Applied Sciences, 8, 2011, 897-902

[7] R. Manjunatha, P. Badari Narayana, K. Hema Chandra Reddy, Application of Artificial Neural Networks for Emission Modelling ofBiodiesels for a C.I Engine under Varying Operating Conditions, modern applied science, 4, 2010

[8] A. Bhaskar Garg, P. Diwan, M. Saxena, Artificial Neural Networks based Methodologies for Optimization of EngineOperations, International Journal of Scientific & Engineering Research, 2012

[9] N. Balajiganesh, B. Chandra Mohan Reddy, Optimization of C.I Engine Parameters Using Artificial Neural', International Journal ofMechanical and Industrial Engineering (IJMIE), 1(2), 2011

[10] A. Mudgal, K. Gopalakrishnan, S. Hallmark, Prediction of Emissions from Biodiesel Fueled Transit Buses using Artificial Neural Networks, International Journal for Traffic and Transport Engineering, 2011

[11] Shivakumar, Srinivas Pai P., Shrinivasa, B. R Rao, B. S. Samaga, Performance and Emission Characteristics of a 4 Stroke C.I.Engine operated on Honge Methyl Ester Using Artificial Neural Network, ARPN Journal of Engineering and Applied Sciences, 2010

[12] Yusuf Cay, Ademcicek, Fuat Kara, SelamiSagiroglu, Prediction of Engine Performance for an Alternative Fuel Using ArtificialNeural Network, Applied hermal Engineering, Elsevier, 2012

[13] K. Sivaramakrishnan, P. Ravikumar, Performance Optimization Karanja Biodiesel Engine Using Taguchi Approach and Multiple Regressions, ARPN Journal of Engineering and Applied Sciences, 2012

[14] A. Karnwal, M. M. Hasan, N. Kumar, A. N. Siddiquee, Z. A. Khan, Multi-Response Optimization of Diesel Engine Performance

Parameters Using Thumba Biodiesel-Diesel Blends by Applying the Taguchi Method and Grey Relational Analysis, International Journal of Automotive Technology, 12(4), 2011, 599−610

[15] D. Tamilvendhan, V. Ilangovan, R. Karthikeyan, Optimization of Engine Operating Parameters For Eucalyptus Oil Mixed Diesel Fueled DI Diesel Engine Using Taguchi Method, ARPN Journal of Engineering and Applied Sciences, 6, 2011

[16] R. Karthikeyan, N. Nallusamy, N. Alagumoorthi, Optimization of Engine Operating Parameters for Turpentine Mixed Diesel FueledDi Diesel Engine Using Taguchi Method, Modern Applied Science, 4, 2010