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AUTOMATION TECHNIQUE FOR ONLINE TRANSESTERIFICATION PROCESS OF BIODIESEL PLANT IN INDIA

KRISHNAMURTHY BHAT[1], BHARATI METI[2] & K. CHANDRASEKHAR[3]

[1]Department of E & IE, Basaveshwar Engineering College, Bagalkot, Karnataka, India

[2]Department of Bio-Technology, Basaveshwar Engineering College, Bagalkot, Karnataka, India

[3]Department of Physics, Basaveshwar Engineering College, Bagalkot, Karnataka, India

ABSTRACT

The fossil fuels are near extinct. There is an immediate need of reliable and sustainable alternate energy source as the world is facing the dangerous energy crisis. Biofuel is most promising and eco friendly alternative energy source. Biodiesel extraction from various vegetable non edible seeds and animal fats is gaining sufficient momentum in India. Sustainability of biodiesel plants and current biodiesel technologies are the issues of concern. Biodiesel plants in India require both monitoring and intelligence of human operators in several aspects and stages. A sustainable biodiesel production must utilize energy-efficient non-conventional process stages, online calculation of Free Fatty Acid (FFA) in raw seed oil, continuous online monitoring of extraction stages and faster/efficient esterification process. Challenges and difficulties in transesterification process, and various automation issues for a biodiesel plant are presented here. In this paper automation method for the complete transesterification process from crude oil handling stage to the biodiesel production is proposed and the practical implementation is initiated.

KEYWORDS: Transesterification, Biodiesel, Automation, Reaction Chamber, Microcontroller, Reaction Time and Rate, Impedance Method, Ph Method

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Original Article

INTRODUCTION

Alternate energy sources are on high demand as the conventional energy is depleting and the need for the fuel is increasing every day. The petroleum reserves of world are reducing day by day. This is leading to the world energy crisis. The situation in India is indifferent from the world. Alternate, sustainable, eco-friendly, safe, non-polluting fuels and cost effective energy sources are the need of the hour today. Over the past decade biofuel is significantly gaining its importance in India. Biodiesel manufactured from vegetable oils or animal fats is excellent candidate to replace common diesel fuel because it is being renewable, non-toxic and often giving rise to reduced exhaust gas emission (lower levels of nitrogen oxide (NOx) emissions). Monoesters produced by the transesterification of vegetable oil with alcohol are known as biodiesel fuels [1]. Biodiesel is a biodegradable and renewable fuel. It contributes no net carbon dioxide or Sulfur to the atmosphere and emits less gaseous pollutants than normal diesel. Carbon dioxide, aromatics, polycyclic aromatic hydrocarbons (PAHS) and partially burned or unburned hydrocarbons emissions are all reduced in vehicles operating on biodiesel [2]. Varieties of feed stocks such as vegetable, animal fats and non edible oils are tried and some are feasible and commercially viable [3]. Biodiesel production from neem (Azadirachta Indica) seed oil is an attractive one as the neem trees are largely grown in India. Contribution of neem seed oil as a source for biodiesel production has gained lots of importance in

India. Shruthi *et al.* have discussed the prospects of neem seed, method of biodiesel production from crude neem oil. The fuel properties of biodiesel from neem oil including flash point-and fire point are studied and presented. The engine properties and emission characteristics under different biodiesel percentages were also studied and presented [4]. Honge (Pongamia Pinnata/ Millettia Pinnata) seed, also known as Karanja seed, is a promising feed stock for transesterification of biodiesel. Honge is a normal sized tree basically used to stop soil erosion by planting them along the highways, roads and canals. The honge seeds contain about 30-32% oil. It is well-adapted to arid zones and has many traditional uses. It is often used for landscaping purposes as a windbreak or for shade due to the large canopy and showy fragrant flowers. These trees can also be grown on waste, barren lands and arid plains. Honge trees are largely grown in North Karnataka in India. The plantation scope and sustainability are narrated by Vigya Kesari *et al.* [5]. The various aspects of Pongamia as potential fuel in India are discussed by Gaurav Dwivedi *et al.*. The study has revealed that brake specific fuel consumption and brake thermal efficiency of B_{20} biodiesel from Pongamia is quite comparable to diesel. The hydrocarbon and carbon monoxide gas emissions are quite low in case of Pongamia biodiesel as compared to diesel [6]. Various other non edible seed oils are also tried and researches are able to present a method of biodiesel extraction. Biodiesel production and fuel properties from non-edible champaca (Michelia Champaca) seed oil for use in diesel engine is explained by Siddalingappa *et al.* [7]. A work is carried out by Gajendra Kumar *et al.* to characterize a system for continuous transesterification of vegetable oil using five continuous stirring tank reactors (5CSTRs). The present work studies the experimental conditions such as catalyst concentration, molar ratio (oil: methanol), reaction temperature, total flow rate, mixing intensity, and the residence time on biodiesel production from coconut oil. The produced biodiesel is analyzed and characterized for their physical and fuel properties including density, viscosity, iodine volume, acid volume, cloud point, pure point, gross heat of combustion, and volatility. The purity and conversion of the biodiesel was analyzed by HPLC. The authors have also noticed that a high stirring speed increased the reaction rate, but an excessive stir speed decreased the reaction rate and conversion to biodiesel. Furthermore, a higher catalyst percentage significantly increased the reaction rate and production capacity [8]. Other seeds/plants which are either tried or tested include rapeseed, canola, soybean, oil palm, sunflower, peanut, flax, safflower, castor seed, tung, cotton, jojoba, jatropha, avocado, and microalgae. In most of the cases Fatty Acid Methyl Ester (FAME) based three stage transesterification process is followed for the production of biodiesel from the oil extracted from these seeds. Either the process or the post esterification characterization is the subject of extensive investigation.

Automation Needs for Biodiesel Plant

Sustainable biodiesel extraction is the need of hour today. Current biodiesel technologies are not sustainable as they require government subsidies to be profitable by the producers and to be affordable by the public. In order to reduce production costs and make it competitive with petroleum diesel, low cost feedstock, non- edible oils and waste cooking oils can be used as raw materials. Net energy benefit can be increased by using high oil yielding renewable feedstock like algae. Additionally, application of energy efficient non-conventional technologies such as ultrasonic and microwave may reduce the energy footprint of the overall biodiesel production. Main reason for non sustainability is energy intensive process steps involved in the production [9]. A sustainable biodiesel production must

- Utilize energy-efficient, non-conventional process stages
- Online calculation of FFA in raw seed oil
- Continuous online monitoring of extraction stages and

- Faster and efficient esterification process.

Veera Gnaneswar Gude *et al.* have also suggested the process optimization using novel heating and mixing techniques, and net energy scenarios for different feedstock from sustainability view of the biodiesel production technologies [9].

Most of the biodiesel plants in India are either offline or semi-automated. They require both human monitoring and intelligence in several aspects and stages. There is an immediate need and scope for

- Mini extraction plant which can be financially and technically feasible for any individual or local authority/agency
- Speeding up the transesterification process and
- Maintenance of quality of esterification process.

All these issues can be addressed by an efficient online automation. The esterification process is sequential in steps and hence automation can be introduced in all stages. Possible automation issues are shown in Figure 1. In order to increase the efficiency and to avoid manual interventions at various stages some of the automations are proposed in Figure 1. It includes calculation of FFA (Free Fatty Acid) content of crude oil, transferring known quantity of feed stock to reaction chamber, estimation of required NaOH and Methanol, stirring control at various stages, temperature control, and most importantly reaction time control. The automated calculation of FFA, transfer of known quantity of feed stock to reaction chamber, estimation of required NaOH and Methanol, stirring control at various stages, temperature control are simple to be implemented. The control complexity of all these are nominal and are implemented in many process and pharmaceutical industries. Most important part of automation here is the on line monitoring of process steady state conditions. The prior work related to monitoring of reaction progress is discussed in the proceeding section.

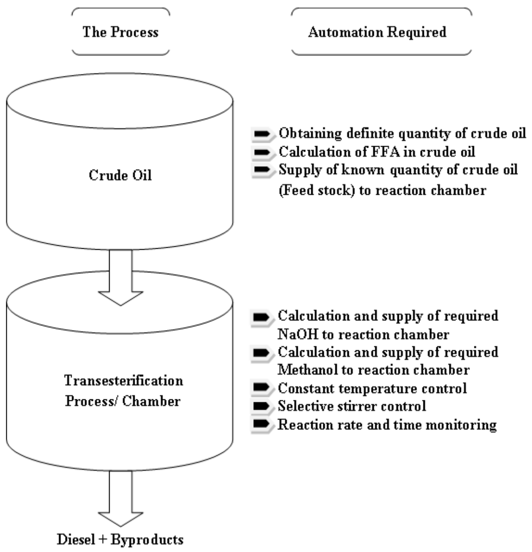

Figure 1: Possible Automation Solutions for Biodiesel Extraction Plant

Prior Work Related to Monitoring of Reaction Progress

The technical paper by Rouhollah Ghanei has the discussion on monitoring of changes in the physical properties for the determination of transesterification progress in oil to biodiesel conversion. Results have shown that the physical properties of fresh oil change during the reaction with a constant rate and the slope of the changes are independent of oil type. Refractive index, specific gravity and viscosity are highly recommended to predict the reaction progress. This approach could be used as an alternative to expensive and time-consuming methods. Though the methods suggested are more suitable for in vitro evaluation, the process can be adopted for the online monitoring purpose also [10]. Optimization of the biodiesel transesterification process is possible by on line monitoring of process steady state conditions. This will help to save energy during the process by reducing mechanical agitation or by reduction of heat energy input [11]. Many techniques and methods are proposed to characterize the biodiesel properties during the reaction process. High precision GC measurement is used to determine product yield (methyl esters) and conversion efficiency. It is unsuitable for low cost industrial process monitoring and control purposes because of requirement of intensive sample preparation and high cost of the equipment. Knothe has investigated the use of a fiber-optic probe based on Near Infra Red (NIR) spectroscopy to monitor the transesterification process [12]. Ellis *et al.*. shown that the shear stress and hence viscosity drops significantly during the reaction process before reaching a steady state value and an acoustic wave solid state viscometer can be used to monitor the shear stress [13]. The use of infrared (IR) spectroscopy to monitor a batch biodiesel reaction is presented by Trevisan [14]. DeBoni employed laser spectroscopy to monitor the transesterification process over a period of 6000s. His results indicated that a steady state was achieved after 2500 seconds [15]. These works suggest that it is possible to use technical methods to monitor the transesterification process and determine state of the reaction during the region controlled by the reaction kinetics and hence, it is possible to employ sensors for feedback control purposes.

Actual Work

We are proposing complete automation from the starting point of handling the raw oil to the production of biodiesel. The proposed work is depicted in Figure 2. The practical implementation of this work is initiated.

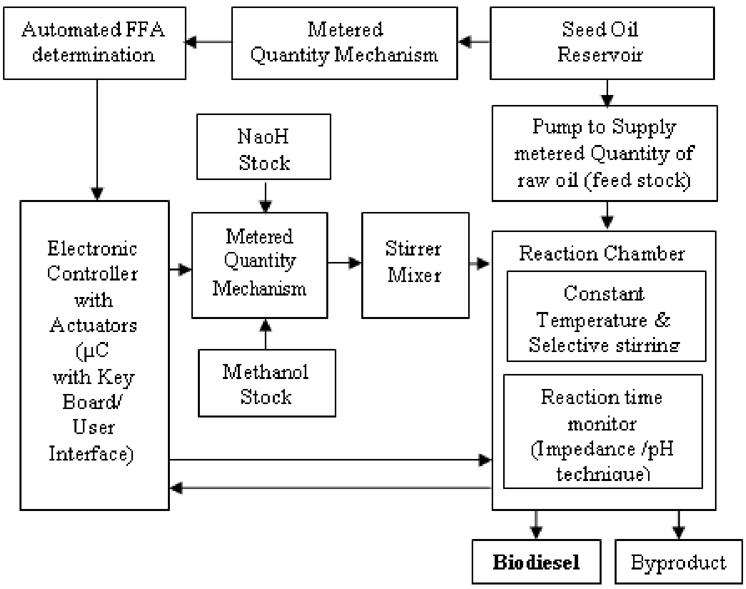

Figure 2: Block Diagram of Proposed Work

A microcontroller is used as central processor/controller to handle various inputs and to drive various actuators. Metered quantity of crude oil from its reservoir is to be obtained by a controlled pumping system and its FFA content is to be calculated by an auto-titration. Based on the FFA content, the required quantity of NaOH and Methanol are to be calculated and administered through a controlled mechanism to the reaction chamber. The reaction chamber temperature and stirring are to be controlled.

Two promising and cost effective methods for monitoring of biodiesel transesterification process considered here are:

- Impedance measurement
- pH measurement

Rachmanto *et al.* proposed a method of measuring impedance which is able to provide information regarding the progress of mass transfer and chemical reaction during biodiesel production. This method uses a simple impedance sensor consisting of two sets of interleaved electrodes (comb shaped) separated by a gap. The electrodes are immersed in the feedstock and an AC excitation voltage is applied across the interleaved electrodes producing an oscillating electric field. The voltage developed across a series resistor is measured and correlated to two important phases of the transesterification reaction, a mass transfer control phase followed by a kinetically controlled phase. The sensor proposed by them is very simple to fabricate, has no moving parts and requires relatively simple electronics. The resulting measurement data is very useful for the control of early stages of the transesterification process and the detection of steady state conditions. It may be possible to use the sensor to detect the process steady state and save energy during the process by reducing the speed of the mechanical agitation after complete mixing has been achieved [16]. Measurement of pH value of feedstock during the reaction is also an attractive and simple method to monitor the reaction. This is experimentally done by William M. Clark. Transesterification of canola oil at 6:1 methanol to oil ratio with 0.5 wt. % KOH as catalyst was studied at 25°C, 35°C, and 45°C. Reaction conversion was correlated to pH measurements and the results were shown to be in agreement with an independent measure of conversion using an enzymatic assay for glycerol. Rate constants obtained from these measurements are consistent with those in the literature. The measured pH change appears to be related to dilution of OH^- ions as the oil is converted to products rather than to depletion of OH^- due to reaction [17]. One of the above two techniques can be implemented to monitor the reaction rate and hence control it for efficiency attainment.

CONCLUSIONS

India has tremendous resources of non edible oil for biodiesel extraction. Current biodiesel technologies and the extraction plants are not sustainable as they require government subsidies to be profitable by the producers and to be affordable by the public. Sustainable biodiesel extraction is the need of hour today. In order to reduce production costs and make it competitive with petroleum diesel, online extraction of biodiesel from the feed stock with maximum extent of automation is proposed in this paper. The implementation of the proposed work is already started and will be a step towards achieving efficiency and sustainability in biodiesel production.

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