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Effect of Electrode Configuration of Transesterification of Chemical Kinetics of Biodiesel Production using High Voltage Electric Field Technique

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Abstract

The objective of this study was to study chemical kinetics of transected biodiesel production under high voltage electric field. Experimental investigation was carried out with methanol and Tung oil at molar ratio of 8:1 with 20 kV power supply for high voltage electric field. The starting of glycerin separation occurred within 1 min after plasma field generation and the process finished after 10 minutes for 100 ml of Tung oil of which the obtained biodiesel was 97 ml.

Study on chemical kinetics of biodiesel production, it was found that apparent activation energy was about 34.97 kJ/mol. The reaction rate equation was best approximated with a pre-exponential factor of 284.18 s^{-1}.

Keywords: Biodiesel; Effects of electrode configuration; Electric Field Technique

Introduction

Fuel oil is an important issue in Laos, especially diesel fuel since each year the Country has to import the fuel with a large number and the price of the oil increases continually. According to the government's renewable energy policy, bio diesel is one of the solutions.

Biodiesel mostly comes from long chain fatty acid molecules derived from vegetable oil or animal fat reacts with alcohol such as methanol or ethanol using catalyst. The reaction is called transesterification of which the yield is biodiesel and glycerin. Under normal heating process to generate the reaction, the operating period needs around 2 hours (Anucha Promwungkwa, 2006). Therefore, there are many research studies to find out the method that could shorten the reaction time. The heat source could come from microwave (Raweepat Singkham, 2010) of which the reaction time under microwave irradiation was between 10 to 50 second with a biodiesel yield of 95%. Noppadol Sirirat (2011) used electric field to generate biodiesel of which the operating period was about 90 s for about 100 ml biodiesel.

In this paper, a use of barrier discharged high voltage electric field to generate biodiesel from Tung oil was considered. The chemical kinetics such as the reaction rate constant and the activation energy of the transesterification process were investigated.

Theory

Transesterification as shown in Fig. 1 is the process of exchanging the organic group R″ of an ester with the organic group R′ of an alcohol. These reactions are often catalyzed by the addition of an acid or base such as KOH of which the result was methyl ester and glycerin. (https://en.wikipedia.org/wiki/Transesterification).

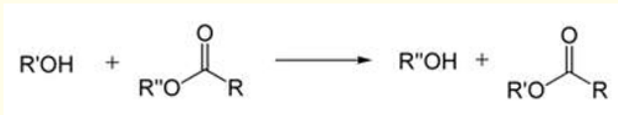

Figure 1: Transesterification: methyl/ethyl alcohol + ester → glycerin + methyl/ethyl ester (https://en.wikipedia.org/wiki/Transesterification).

Diasakou et al. (1998) gave three-steps mechanisms of the methanolysis reaction of triglycerides to methyl esters as

$$\text{Three steps:}\quad \begin{aligned} &TG + MeOH \xrightarrow{k} DG + ME \\ &DG + MeOH \xrightarrow{k} MG + ME \\ &TG + 3MeOH \xrightarrow{k} G + 3ME \end{aligned} \qquad (1)$$

Where TG = triglycerides, MeOH = methanol, G = glyceride, ME = methyl esters, DG= diglycerides, MG = monoglycerides, respectively.

Firstly, triglycerides were converted to diglycerides, then to monoglycerides, and finally converted to glycerides and methyl ester which was biodiesel.

Kusdiana and Saka (2001) simplified the three-step Diasakou's mechanisms to one step as:

$$\mathrm{TG} + 3\mathrm{MeOH} \xrightarrow{\mathrm{k}} \mathrm{G} + 3\,\mathrm{ME}\,. \qquad (2)$$

One mole of triglycerides reacts with three moles of methanol yield one of glycerin and three moles of methyl esters.

The reaction rate of the chemical reaction could be evaluated by

$$\mathrm{r} = -\frac{dC_{TG}}{dt}$$

and

$$\mathrm{r} = \mathrm{k}C_{\mathrm{TG}}^{\mathrm{m}}C_{\mathrm{MeOH}}^{\mathrm{n}}\,. \qquad (3)$$

Where r = reaction rate, k = constant of reaction, with temperature changes m = reaction order with respect to triglycerides concentration, n= reaction order with respect to methanol concentration. C_{TG} = triglycerides concentration and C_{MeOH} = methanol concentration.

The reaction rate (r) is normally simplified for m=1, n=0, then

$$r = kC_{TG}^{m} \text{ or}$$

$$r = -\frac{dC_{TG}}{dt} = kC_{TG}. \quad (4)$$

After integration, we obtained

$$\ln C_{TG,t} = -kt + \ln C_{TG,0}. \quad (5)$$

Where C_{TG}, t and C_{TG}, 0 are triglycerides concentration at time (t) and at the beginning (t = 0), respectively. The constant of reaction (k) is the slope of graph ln C_{TG}, v.s. t.

The rate constant also depends on activation energy (Ea) and temperature of reaction (T) as

$$r = k_o C_{TG}\, e^{-Ea/RT}. \quad (6)$$

At any time, the temperature of reaction is changing then the instantaneous value of k is varying and the relation of the k value with time is given in a form of

$$\ln k = \ln k_o^{\,-Ea/RT}. \quad (7)$$

With the local values of T and k, then the value of Ea could be evaluated.

Experimental Setup

Fig. 2. shows a test rig of our experiment. Methanol at 133 ml with KOH 1.1 mg was mixed with Tung oil at 133 ml in a cylinder. The molar ratio of methanol and Tung oil was 8:1. A high voltage electric field was generated by a 20 kV electrical supply.

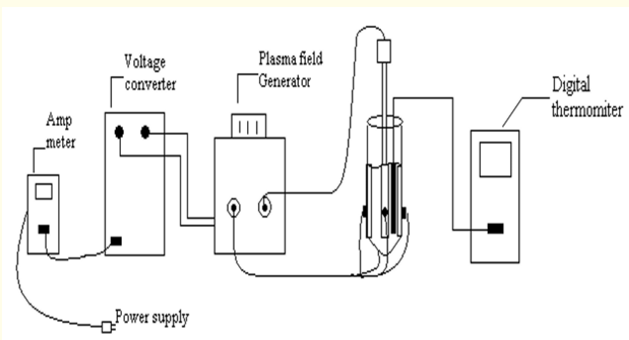

Figure 2: Experimental setup of biodiesel production under high voltage electric field.

Results and Discussions

Fig. 3. shows experimental data of C_{TG} at various operating time. The slope of the graph showed the average value of k from the starting of the reaction until the process ended. The k value was found to be higher than that of other method (Anusan Permsuwan, 2011) which meant that high voltage electric field gave a quick reaction rate.

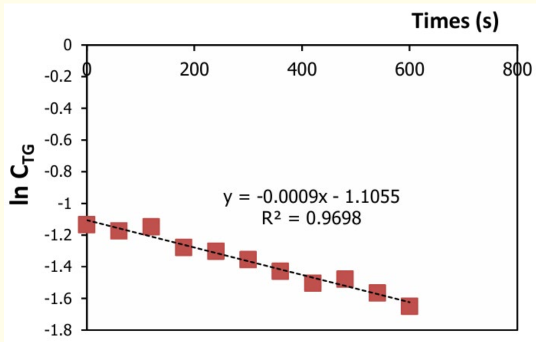

Figure 3: Reaction rate of biodiesel process by high voltage electric field.

The instantaneous values of *k* at any operating time t were plotted as shown in Fig. 4. The slope of the graph was the value of activation energy, Ea.

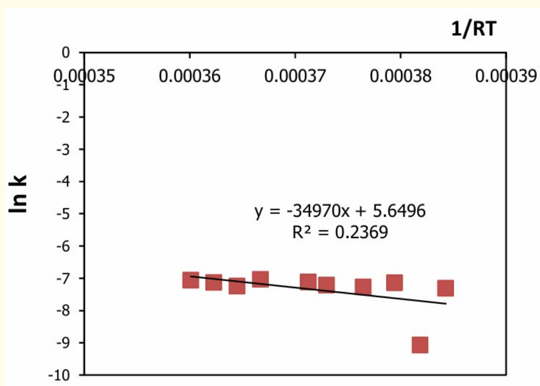

Figure 4: Arrhenius plot of ln *k*.

The value E_a was found to be 34.97 kJ/mol which was lower than that of the other method which meant that our technique consumed less energy for the reaction.

Conclusion

Transesterification reaction of Tung oil and methanol for biodiesel production under a high voltage electric field was investigated. In the study, a high voltage electric field was generated with 20 kV electrical power. Relevant kinetic data were determined. It could be noted that apparent activation energy was about 34.97 kJ/mol.

Acknowledgment

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