Effects of electrode configuration on chemical kinetics of Biodiesel production with electric field

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Abstract: This paper presented chemical kinetics of biodiesel transesterification under electric field. A barrier discharge technique was carried out with 2 and 4 electrodes attached at outside and 1 electrode inside of a glass cylinder contained crude vegetable oil and methanol. The composition of the crude oil and methanol was 1:6 by mol. Crude Tung oil and crude palm oil were raw materials with an amount of 100 ml. The operating periods were 50 s and 420 s for Palm oil and Tung oil, respectively. About 91 % and 88.5 % of biodiesel were found from the crude oils, respectively. With 3 and 5 electrodes, the chemical kinetics for the reaction rate \( r \) could be

\[
\text{Plan oil: } r = 0.081 C_{H_2} e^{-\frac{27106}{RT}} \quad \text{for three electrode,} \\
\text{Tung oil: } r = 0.003 C_{H_2} e^{-\frac{35024}{RT}} \quad \text{for five electrodes,}
\]

for three electrode, for five electrodes,

\[
\text{Plan oil: } r = 0.088 C_{H_2} e^{-\frac{31081}{RT}} \quad \text{for five electrodes,} \\
\text{Tung oil: } r = 0.001 C_{H_2} e^{-\frac{82800}{RT}} \quad \text{for five electrodes.}
\]

1. Introduction

Fuel oil is an important issue in Laos, especially diesel fuel since each year the Country has to imports 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, 2549). 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, 2553) of which the reaction time under microwave irradiation was between 10 to 50 second with a biodiesel yield of 95%. Noppadol Sirirat (2554) used electric field that is Electrolysis discharge to generate biodiesel of which the operating period was about 90 s for about 100 ml biodiesel.

In this paper, a use of electric field. A barrier discharge technique was carried out with 2 and 4 electrodes attached at outside and 1 electrode inside. Generate biodiesel from plan oil and Tung oil was considered. The chemical kinetics such as the reaction rate constant and the activation energy of the transesterification process were investigated.

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2. 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. (http://en.wikipedia.org/Transesterification).

![Figure 1. Transesterification: methyl/ethyl alcohol + ester → glycerin + methyl/ethyl ester](http://en.wikipedia.org/wiki/Transesterification).

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

\[
\text{TG} + \text{MeOH} \xrightarrow{} \text{DG} + \text{ME}
\]

Three steps:

\[
\text{DG} + \text{MeOH} \xrightarrow{} \text{MG} + \text{ME}
\]

\[
\text{TG} + 3\text{MeOH} \xrightarrow{} \text{G} + 3\text{ME}
\]

Where $\text{TG} =$ triglycerides, $\text{MeOH} =$ methanol, $\text{G} =$ glyceride, $\text{ME} =$ methyl esters, $\text{DG} =$ diglycerides, $\text{MG} =$ 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:

\[
\text{TG} + 3\text{MeOH} \xrightarrow{k} \text{G} + 3\text{ME}.
\]

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

\[
r = \frac{-\frac{dC_{\text{TG}}}{dt}}{}
\]

and

\[
r = kC_{\text{TG}}^mC_{\text{MeOH}}^n.
\]

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. $C_{\text{TG}} =$ triglycerides concentration and $C_{\text{MeOH}} =$ methanol concentration.
The reaction rate \( r \) is normally simplified for \( m=1 \), \( n=0 \), then

\[
\frac{dC_{TG}}{dt} = kC_{TG}.
\]  

(4)

After integration, we obtained

\[
\ln C_{TG,t} = -kt + \ln C_{TG,0}.
\]  

(5)

Where \( C_{TG,t} \), \( t \) 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 \( (E_a) \) and temperature of reaction \( (T) \) as

\[
r = k_o C_{TG} e^{-E_a/RT}.
\]  

(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

\[
\ln k = \ln k_o - \frac{E_a}{RT}.
\]  

(7)

With the local values of \( T \) and \( k \), then the value of \( E_a \) could be evaluated.

3. Experimental Setup

Fig.2. shows a test rig of our experiment. Methanol at 133 ml with KOH 1.1 mg was mixed with Plan oil and Tung oil at 100 ml in a cylinder. The molar ratio of methanol and Tung oil was 8:1. Under Electric field was DC generated by a 10 kV electrical supply.

4. Results and Discussions

4.1. Effect of electrode formatting

Test results of each characteristic of the electrode that affects the reaction Biodiesel oil generation and Glycerine continues to be tested in the Tung oil and palm oil. That uses three electrodes And five electrodes type It was found that the time that resulted in the occurrence of % yield of Biodiesel As shown in Figure 3 and Figure 4.
Figure 3. Comparison of reaction time with the characteristics of three electrode and five electrode bars using palm oil

Figure 4. Comparison of reaction time with % yield of the characteristics of three electrode and five electrode using the Tung oil

4.2 Chemical kinetics of reaction rate

From the temperature relationship and Time of the reaction. Will give up the decline of $C_{TG}$ at any time shown in Figure 5 and 6 from the slope of the graph Shows the reaction constant ($K$) from the first reaction until the process ends.

Figure 5. Reaction rate of biodiesel production process by formatting three electrodes and five electrode in palm oil
Figure 6. Reaction rate of biodiesel production process by formatting three electrodes and five electrode in the Tung oil.

From the slope of the graph showing $E_a$ Activation, which has a high activation energy, indicating that this reaction is more difficult.

Figure 7. Graph showing the relationship between and $1/RT$ Palm oil.

Figure 8. Graph showing the relationship between and $1/RT$ of Tung oil.
In this research, biodiesel is produced from transesterification reaction of palm oil and Tung oil, and methanol by the form of electrodes in the electric field With a voltage of 10 kV which is determined by the reaction of chemical kinetics In palm oil using Three-electrode found that $E_a = 27.106$ J/mol and in the five electrode electrodes $E_a = 31.081$ kJ/mol, respectively, and in the rocky oil in the stone Three-electrode electrodes found that $E_a = 35.042$ kJ/mol and in five electrode found that $E_a = 35.828$ kJ/mol, respectively.

5. References
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