Enhance the Esterification Reaction Rate in Producing Biodiesel by Microwave and Fe Powder

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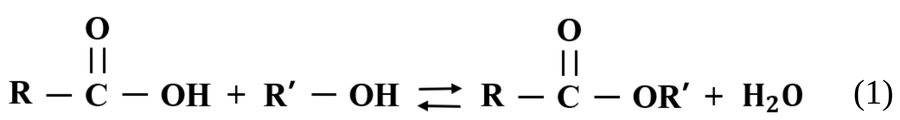
Abstract

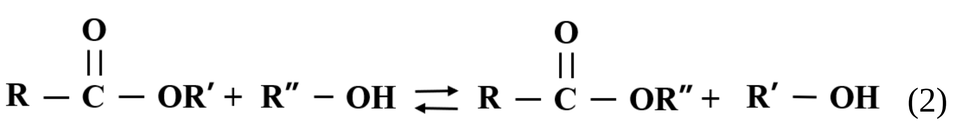
In the biodiesel production process, esterification is an essential step, but it typically consumes a considerable amount of time before meeting the criteria for proceeding to the next phase, the transesterification reaction. Based on the previous work in our laboratory, we have demonstrated a stirring cavity utilizing a 2.45GHz microwave, which enhanced esterification reaction employing a molar ratio of 1.15 of glycerol to oleic acid to approximately 1.3 times faster than the conventional method, which typically takes over 6 hours. In this study, we demonstrate an improved esterification reaction introducing iron powder as a catalyst. As a result of these enhancements, we achieved a significant improvement, which was about 13 times faster than the conventional method.

I. Introduction

Biodiesel is considered an appealing alternative fuel, derived from sustainable feedstocks like waste cooking oil. To synthesize biodiesel from waste cooking oil, the oil undergoes an esterification reaction (1) followed by a transesterification reaction (2). Given that the esterification reaction typically requires five times more time than the transesterification reaction, which takes more than 6 hours, our focus lies in accelerating the esterification reaction through microwave-assisted heating.



(1)



(2)

Table 1 Ingredients and conditions in this work.

Ingredients and Conditions			
Ingredients	Soybean oil	Oleic Acid	Glycerol
Mass ratio	100	100	37.45
Molar ratio	1.18	1	1.15
Microwave Frequency	2.45GHz		
Microwave Power	1300W		
Heating Temp.	200 ˚C		
Vacuum	160 Torr		

II. Stirring Microwave Cavity

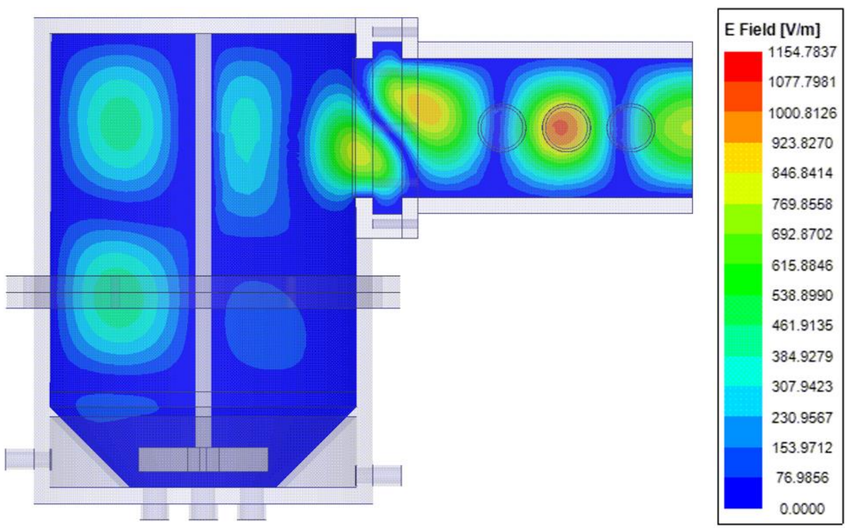


Fig. 1 The cavity structure and simulated electric field distribution.

Besides showing cavity structure, Fig. 1 also demonstrates the electric field distribution, and the declining electric field in the oil displays that the oil absorbs microwave quite well. Based on this result, and that the magnetic materials can assemble the electric field, we chose Fe powder as a catalyst to conduct the experiment.

III. Results

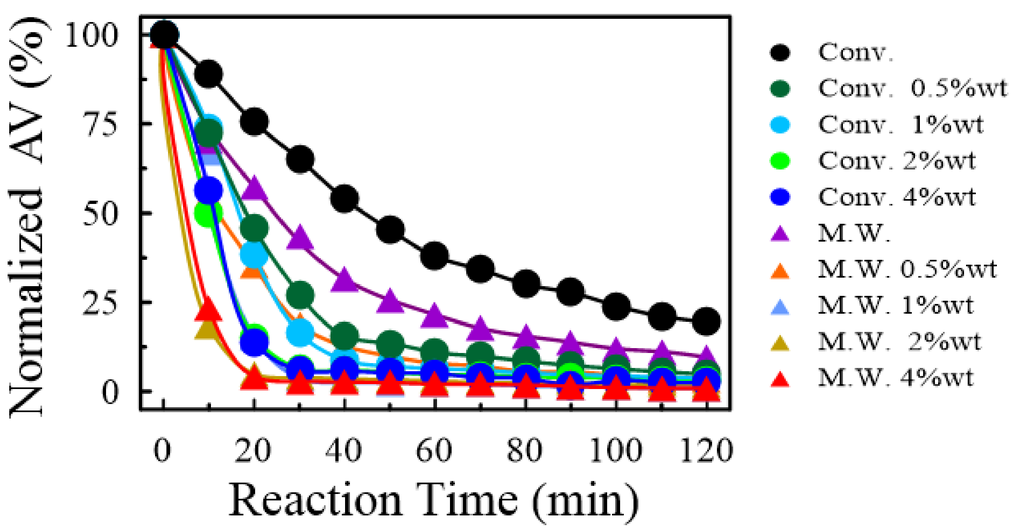


Fig. 2 Normalized acid value under different weight concentration of Fe powder.

The experiments were conducted with different weight concentration of Fe powder under both microwave-heating and conventional process. Figure 2 shows that when the concentration rises, the declining rate of AV also rises, and the microwave process is more efficient than conventional one at each temperature. An essential examination of the biodiesel is that the acid value should be less than 3 mg[NaOH]/g, and the 4%wt microwave process reach the requirement in about 30 minutes. Assume that the esterification reaction is a first-order reaction, we can follow the equation (3) to get the reaction rate constant (Table 2). It shows that the microwave process is about 1.3 times faster than the conventional one.

$$\ln[A]_t = -kt + \ln[A]_0 \qquad (3)$$

Table 2 Reaction rate constant under different weight concentration of Fe powder.

Normalized Reaction Rate Constant k		
wt%	Conv.	M.W.
0	1.21	1.62
0.5	4.03	4.67
1	5.45	9.69
2	8.04	12.90
4	8.43	13.58

IV. Saturation Curve

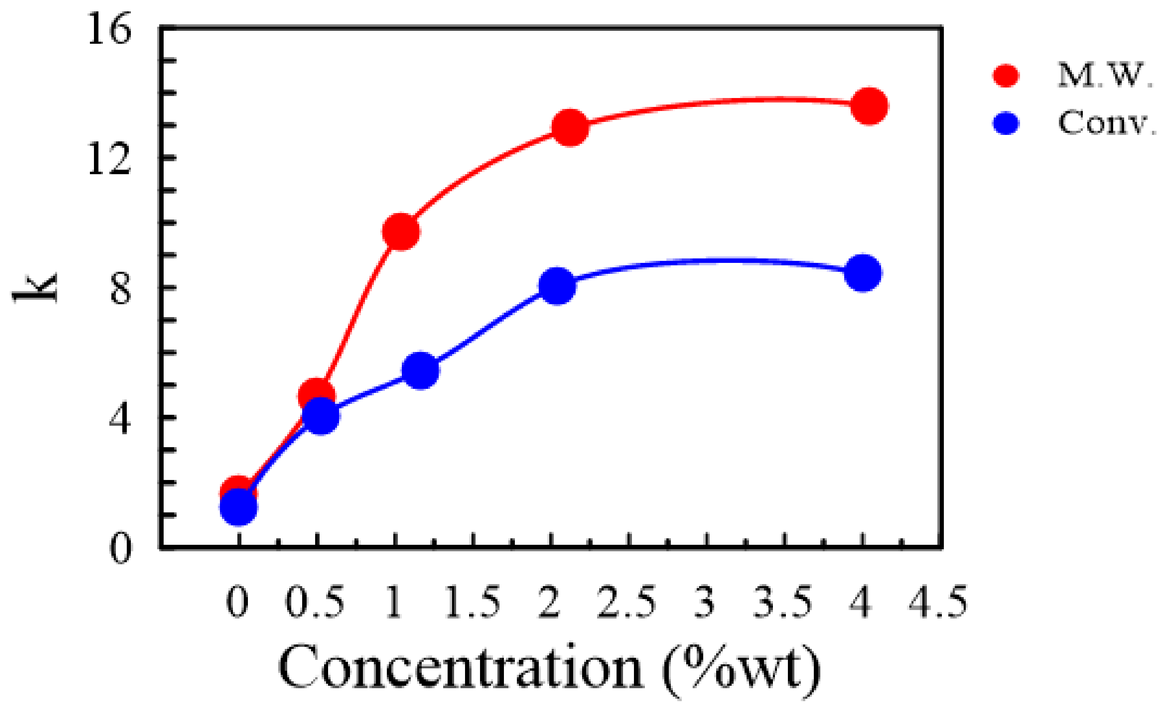


Fig. 3 Reaction rate constant plot with respect to concentration of Fe powder.

From Fig. 3 we can know that there is a saturated concentration near 4%wt, and the maximum reaction rate indicates that the esterification reaction can be completed within about 30 minutes. We have found a method to enhance the esterification reaction with a lot of potential to be industrialized. By some appropriate methods to separate the Fe powder from the oil, the powder could be recycled and applied back to the esterification reaction over and over again.

V. Reference

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