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ScienceDirect

Procedia Environmental Sciences 28 (2015) 204 – 213

Procedia Environmental Sciences

The 5th Sustainable Future for Human Security (SustaiN 2014)

Biodiesel production in supercritical methanol using a novel spiral reactor

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Abstract

Biodiesel was produced via non-catalytic transesterification in supercritical methanol using a novel spiral reactor. This spiral reactor could serve as a heat exchanger, thus it provided the advantage of being able to recover the heat. Transesterification was carried out at 270–400 °C, a pressure of 20 MPa, oil-to-methanol molar ratio of 1:40, and reaction time of 3–30 min. Using this technique, a complete conversion of fatty acid methyl ester (FAME) (100 wt%) was obtained in a short reaction time of 10 min at 350 °C and oil-to-methanol molar ratio of 1:40 under a reactor pressure of 20 MPa. The result revealed that biodiesel yield conducted in spiral reactor is higher than that in batch reactor at the same reaction conditions. The kinetic model of canola oil conversion to biodiesel in supercritical methanol was also determined.

Peer-review under responsibility of Sustain Society

*Keywords:*biodiesel;methanol;spiral reactor;supercritical fluid

1. Introduction

Nowadays, many countries around the world have placed focus on the development and application of renewable energy technologies as a consequence of the depletion of global fossil fuel reserves and to mitigate environmental

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Peer-review under responsibility of Sustain Society
doi:10.1016/j.proenv.2015.07.027

damage. Biodiesel, which is ordinarily produced by transesterification of vegetable oils, animal fats, or waste oils with short chain alcohol, has been considered as one of the most promising renewable energy sources as a conventional diesel fuel substitute owing to its numerous comparative advantages such as low carbon monoxide, particulate matter, and unburnt total hydrocarbon emission[1].

Homogeneous alkali-catalyzed transesterification is mainly used to produce biodiesel in developing countries since these catalyst are widely available. However, this method has drawbacks such as low free fatty acid and water content requirements, soap formation, longer reaction time, lower reaction rates, and strict reaction conditions.

In order to circumvent the problem, a new breakthrough of non-catalytic biodiesel production under supercritical conditions has been proposed by Saka and Dadan[2]. This technology promises a lot of advantages such as no catalyst requirement, no waste water generated, easier separation, and higher reaction rates. However, this technology still remains the drawback regarding heat recovery that has been difficult for commercial application. Therefore, a novel spiral reactor, which is composed of a parallel tube heat exchanger where heat is recovered and high-temperature transesterification reactor where the reaction mainly takes place, is proposed. The objective of this study is to develop a novel spiral reactor for transesterification reaction between canola oil and methanol under supercritical conditions. For this purpose, the effect of temperature and reaction time on FAME yields was investigated. In addition, the comparison between batch and spiral reactor in terms of temperature effect on biodiesel yield was also evaluated.

Nomenclature

A	pre-exponential factor
Ea	activation energy
k	reaction rate constant
R	universal molar gas constant
t	residence time
T	temperature

2. Material and Methods

2.1. Reagents and materials

All of the chemicals were used in this study without further treatment. The chemical reagents used was methanol (99.0%) purchased from Nacalai Tesque, Inc., Kyoto, Japan. The standard compounds used in this study were the same with those reported in our previous paper[3].

2.2. Experimental

Biodiesel production was carried out in the spiral reactor that was schematically illustrated in Fig. 1. The spiral reactor was made of stainless-steel tubing (SS316) with an inner diameter of 2.17 mm. Thermocouples were equipped to measure the flow temperature. The length of the heat exchanger part was 2.5 m and that of the reactor portion was 10 m. This spiral reactor was buried in heat transfer cement with a cartridge heater in the center of the spiral reactor. First, the feedstocks consisted of canola oil and methanol were fed to the reactor using a high-pressure pump. Subsequently, the pressure was increased to 20 MPa using a back-pressure regulator. The samples were collected after achieving steady state. The effluent was cooled down, removed from the reactor, and depressurized with a back-pressure regulator.