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Distillation of Pyrolytic Oil Obtained from Fast Pyrolysis of Plastic Wastes

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Abstract

Fast pyrolysis of plastic wastes, at temperatures from 500-800ºC, gives as a main product, a dark brown liquid (a mixture of gasoline, diesel and heavy oils). Fractional distillation is commonly used to separate petroleum oils. However, information on the distillation of the pyrolytic oil obtained from fast pyrolysis of plastic wastes is scarce. We studied the distillation of two pyrolytic oil samples derived from fast pyrolysis of polyethylene and mixed plastic wastes. The former was distilled at the temperature of 180ºC for 60 minutes and the latter was distilled at the temperature of 150ºC and 180ºC for 90 minutes. We observed that the distillates had a lighter color than the pyrolytic oil samples. The distillates were light yellowish at 180ºC and colorless at 150ºC. In the early stage of distillation, distillation rates increased with elapsed time and reached a maximum at approximately 25-35 mL/min and then gradually dropped. The distillates had lower densities and viscosities than the pyrolytic oils and both distillate properties were similar to those of gasoline, i.e. densities of 706-728 kg/m^3 and viscosities of 0.39-0.43 $\times 10^{-6} m^2 s^{-1}$.

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Keywords: Alternative energy; distillate; gasoline; plastic waste; fast pyrolysis

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1. Introduction

The raw pyrolytic oil obtained from commercial rotary kiln pyrolysis for municipal plastic waste contained a wide range from compounds from C_5 about C_{25} as well as other products [1]. This pyrolytic oil represents renewable energy. For example, blends of 'plastic' oil from catalytic pyrolysis of waste high density polyethylene (HDPE) with

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diesel was tested in a compression ignition (CI) engine [2]. The result showed brake specific fuel consumption (BSFC) increases with increase in waste plastic oil blend ratio and decreases with increase in engine load. Mechanical efficiency increases with brake power at all blend ratios. In addition, the carbon monoxide (CO) emission for almost all loads and all blends was lower than for diesel.

The pyrolytic oil obtained from fast pyrolysis has been separated and improved with various distillation methods, catalytic and molecular distillations and vacuum fractional distillation. Wang et al. [3] adopted the methanol-water method to enrich pyrolytic lignins in the heavy fraction of bio-oil by molecular distillation. The gasoline and diesel like fuels from waste tire oil (WTO) was produced by using catalytic distillation [4]. The WTO in produced fuels was 18%, 70%, and 12% by weight for the light fuel, heavy fuel, and other product, respectively. Choi et al. [5], took crude bio-oil from brown algae (Saccharina japonica) and separated it into four fractions in a vacuum fractional distillation column. Three fractions condensed as distillate according to the controlled distillate temperature and bottom fraction was solid residue. However, study of distillation of the pyrolytic oil obtained from fast pyrolysis of plastic wastes is scant. Therefore, we aimed to study the product obtained from pyrolytic oil from polyethylene and mixed plastic wastes.

2. Methods

2.1 Raw materials

Gasoline and diesel oil were purchased from common commercial PTT oil stations in Thailand. The pyrolytic oil was collected from fast pyrolysis process of polyethylene and mixed plastic wastes. The fast pyrolysis operates at a heating rate of 10ºC/min up to 420ºC in a laboratory scale reactor.

2.2 Distillation of mixture of gasoline and diesel oil

Type K thermocouples were installed in 6 positions: re-boiler, cooling water inlet and outlet, outside column environment, vapor phase and distillate. 5 liters of 1:1 by volume gasoline and diesel oil mixture was poured into the re-boiler and then heated at temperatures between 70-200ºC, i.e. the range of boiling points of the components of gasoline and diesel oil. Cooling water flow rate was set at 20 liters per minute. The distillation column is a 10 tray fractionation column. The temperature was recorded every minute for 1 hour. Time from the first drop of distillate and then for every 500 ml of distillate for an hour and distillate volume were recorded. The distillate was kept in a glass bottle in a dark place. The first drop of distillate, maximum vapor temperature and mixture in reboiler temperature at steady state was illustrated as Fig. 1.

2.3 Distillation of pyrolytic oil obtained from fast pyrolysis of plastic waste

In this section, we ran two sets of experiments to distill pyrolytic oil obtained from (a) polyethylene waste (opaque plastic bottles) and (b) mixed plastic waste. The distillation procedure was similar to that in Section 2.2: we only changed the temperature at the re-boiler to 180ºC with 1 hour of operation for polyethylene and 150-180ºC with 1.5 hours for mixed plastic.

2.4 Determination of properties of distillate product

The calorific value of the distillate product was tested using a bomb calorimeter (Gallenkamp model adiabatic). The viscosity was measured by timing oil flow through viscometer number 50 and calculated from

$$\text{Viscosity} = \text{calibration constant x time} \qquad (1)$$