Characteristics of Pyrolysis Oil from Mixed Plastic Wastes by Low Temperature Pyrolysis

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1. Introduction

The generation of waste plastics has been increasing, but there are not enough the treatment and recycling methods for waste plastics. Interests of pyrolysis technology for the treatment of polymer such as plastic are growing recently. The advantage of the pyrolysis using plastic waste is that the waste can be changed into fuel and raw materials for the petrochemical industry. Therefore, this study was carried out on the pyrolysis to treat the mixed plastic wastes with PS, PP, HDPE and LDPE. We also conducted petroleum quality inspections and property analyses for assessment of practical use of pyrolysis oil.

2. Experimental material and methods

The four types of plastic waste (PS, PP, HDPE, LDPE) were collected from waste recycling centers. The samples were dried in dry oven, then they were shredded into approximately 1cm-size particles. It was sufficiently mixed to hormonize plastic waste.

A schematic diagram of the pyrolysis system is shown in Fig. 1. In the experiment, sample (200g) was entered into reactor and nitrogen was purged to make an oxygen-free atmospheric condition interior of the reactor. The pyrolysis of the mixed plastic wastes were performed in the range of 375~475°C for 300min and heating rate was 10°C/min. The decomposed gas was condensed by a condenser. The yields of liquid pyrolysis products were determined by weighing condensed liquid products. The pyrolysis oil were analyzed by a gas chromatography and bomb calorimeter. The pyrolysis oil was also compared to the petroleum quality inspection method on KS.

![Fig. 1. Schematic diagram of pyrolysis system. (1:Nitrogen bomb; 2:Flowmeter; 3:Heating jacket; 4:Reactor; 5:Thermocouple; 6:Temperature controller; 7:Condenser; 8:Water circulator; 9:Separator; 10:Reservoir)](image)

3. Results and Discussion

From the experimental results, it was presented that the higher of pyrolysis temperature, the more oil was gained. However, the quantity of pyrolysis oil were decreased over 475°C, but the gas was increased as shown fig. 2.

As a result of analysis of carbon numbers for pyrolysis oil using a gas chromatography, styrene monomer content was high, styrene monomer and C2~C11 compounds were decreased, and C12~C24 compounds were increased according to raising pyrolysis temperature. The optimum pyrolysis temperature was 425°C for the high yield of C2~C11 hydrocarbon compounds as shown fig. 3.

As shown in table 1, the heating values of pyrolysis oil converted from mixed plastic wastes were 44,800~45,250J/g, and pyrolysis oil was enough to satisfy the regulation of fuel oil except the ignition point.

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Fig. 2. Effect of temperature on the accumulated oil conversion rate of mixed plastics.

(a) 375°C  (b) 400°C  (c) 425°C

Fig. 3. Carbon number distributions of pyrolysis oil from mixed plastics at different temperature.

Table 1. Property analysis for oils as a result of pyrolysis of mixed plastics

<table>
<thead>
<tr>
<th></th>
<th>375°C</th>
<th>400°C</th>
<th>425°C</th>
<th>Fuel Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating Value (J/g)</td>
<td>44,800</td>
<td>45,000</td>
<td>45,250</td>
<td>-</td>
</tr>
<tr>
<td>Sulfur component (wt. %)</td>
<td>0.04</td>
<td>0.03</td>
<td>0.03</td>
<td>below 0.1</td>
</tr>
<tr>
<td>Ignition point(℃)</td>
<td>23.0</td>
<td>25.5</td>
<td>27.0</td>
<td>over 40.0</td>
</tr>
<tr>
<td>Kinematic viscosity(40℃)(mm²/s)</td>
<td>1.1</td>
<td>1.4</td>
<td>1.8</td>
<td>0.9~1.8</td>
</tr>
<tr>
<td>Pour point(℃)</td>
<td>-39.0</td>
<td>-32.5</td>
<td>-39.0</td>
<td>below -20.0</td>
</tr>
<tr>
<td>Cd(mg/L)</td>
<td>0.06</td>
<td>0.04</td>
<td>0.05</td>
<td>below 1</td>
</tr>
<tr>
<td>Pb(mg/L)</td>
<td>0.01</td>
<td>0.17</td>
<td>0.23</td>
<td>below 1</td>
</tr>
<tr>
<td>Cr(mg/L)</td>
<td>0.07</td>
<td>0.10</td>
<td>0.11</td>
<td>below 1</td>
</tr>
<tr>
<td>As(mg/L)</td>
<td>0.16</td>
<td>0.35</td>
<td>0.27</td>
<td>below 1</td>
</tr>
</tbody>
</table>

4. Conclusions

In the pyrolysis experiment using mixed plastic wastes, amount of generated gas was increased over 475°C. In contrast, amount of generated oil decreased. As a result of analysis of carbon numbers for oil, styrene monomer content was high, styrene monomer and C₅-C₁₁ compounds were decreased, and C₁₂-C₂₄ compounds were increased according to raising pyrolysis temperature. The optimum pyrolysis temperature was 425°C for the high yield of C₅-C₁₁ hydrocarbon compounds. Heating values of pyrolysis oil converted from mixed plastic wastes were 44,800~45,250J/g which was lower than light oil(49,000J/g), but it showed that the pyrolysis oil can be used as fuel. In the result of petroleum quality inspection of pyrolysis oil, pyrolysis oil was enough to satisfy the regulation of fuel oil except the ignition point. It can be verified that the quality of pyrolysis oil from mixed plastic wastes was sufficient for using as fuel oil.