Gasification of Waste Tire with ZnO as an Oxidant for Solar Energy Utilization

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Abstract - Waste tire (main component = carbon) will be utilized as a useful material for conversion of solar energy into chemical energy by a solar thermochemical gasification into CO gas using concentrated solar energy. In the present paper, the gasification of a waste tire (C 86%, H 8.4%) was studied using ZnO as a donor of oxygen in the infrared furnace at 1373K. After 20 sec, most of H2 in the tire sample was converted into molecular H2 and C~(H2:C~=62:29) and 71 mole% of C was gasified to CO(36%), CH4(29%), C2H4(2%), and CO2(4%). CO2 was about 1/10 of CO quantity, indicating that carbon in the waste tire can be converted effectively to gaseous fuels. In the experiment without ZnO, the conversion in the gasification of C and H were decreased to 17% for carbon and 77% for hydrogen. The volume of evolved CO2 in the gasification of waste tire with ZnO was less than in the combustion of waste tire.

I. INTRODUCTION

In Japan, the number of cars ranks second in the world, and 800,000 tons of waste tires are produced per year. It causes waste disposal problems. And also about 10% of oil is used for the production of organic commodities, which are treated mostly by landfilling. Since waste tire contains carbon as main component, it can be converted to fuel gas by water gas reaction. This reaction needs the high temperature process heat energy at around 1000°C. However, using concentrated solar energy at around 1000°C, the solar energy can be converted into chemical energy of the fuel gas, since the water gas reaction is the endothermic. The process heat required for the endothermic heat can be supplied from concentrated solar energy. Thus, waste tire will be utilized as a useful material for solar energy converter. In this paper, gasification of the waste tire using ZnO as a donor of oxygen in infrared furnace was studied to elucidate feasibility of solar energy conversion into chemical energy by this reaction system.

II. EXPERIMENTAL SET-UP

The experimental apparatus is shown in Figure 1. It consists of a 10 mm diameter, 400 mm length, tubular quartz reactor that contains a bed of solid reactants. ZnO powder (Wako Pure Chemical Ind. Ltd, size smaller than 400 mesh or 37 μm) and waste tire chips (1-2mm length) was mixed at ZnO/carbon in waste tire molar ratio=1. The mixed sample was set in the sample feeder of vinyl chloride tube( 8 mm diameter, 50 mm length), that was jointed to the tubular quartz reactor with a silicon tube. The reactor was heated in an infrared furnace. The sample was dropped to the bed in the reactor and Ar (from 10 to 15 cm3 min⁻¹) was passed through the reactor. Evolved gases were determined by gas chromatography (Shimadzu G6C-8A, equipped with Porapak Q or Molecular Sieve 13X column).

III. RESULTS AND DISCUSSION

Figures 2 and 3 show the rates of gas evolution (cm³ sec⁻¹) at 1373K as a function of reaction time, for the
waste tire chip samples with ZnO and without ZnO, respectively. For the sample with ZnO (Fig. 2), the maximum of the rates of gas evolution for H₂ and CH₄ (Curves A and B) were observed at the early stage, and that for CO (Curve C) was at 70 sec from the start of reaction. In all the three kinds of gases, the rate of gas evolution was greater for ZnO mixture sample than that of without ZnO, indicating that ZnO accelerates the gas evolution by the thermal degradation of waste tire. The duration of the maximum of the CO gas evolution rate for the sample with ZnO suggests that the reaction of carbon in the waste tire with ZnO starts after the completion of the gasification reaction of the hydrogen in the waste tire sample. Table 1 lists the percentage of the product gas contents and the unreacted portion. They were evaluated on a mole basis for carbon and hydrogen. The data for Table 1 was obtained for the collected gas sample during the 20 sec-heating. After 20 sec, most of H₂ in the tire sample was converted into molecular H₂ and CH₄ (H₂:CH₄=62:29) and 71 mole% of C was gasified to CO (36 %), CH₄ (29 %), C₂H₆ (2 %), and CO₂ (4 %). The CO₂ was about 1/10 of CO quantity, indicating that carbon in the waste tire can be converted effectively gaseous fuels. In the experiment without ZnO, the conversion in the gasification of C and H were decreased to 17% for carbon and 77% for hydrogen. The volume of evolved CO₂ in the gasification of waste tire with ZnO was less than in the combustion of waste tire. Thus, about 40% of the gasification of the waste tire using ZnO occurs according to the gasification of carbon with ZnO (C + ZnO = CO + Zn), which is endothermic (ΔH=360kJ at 1373K). This suggests that the gasification of the waste tire using ZnO can be used for conversion of solar energy into chemical energy using concentrated solar beam.

Fig. 2. Rates of gas evolution at 1373K as a function of reaction time for waste tire chips with ZnO. (A:H₂, B:CH₄, C:CO)

Fig. 3. Rates of gas evolution at 1373K as a function of reaction time for waste tire chips without ZnO. (A:H₂, B:CH₄, C:CO)

<table>
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<tr>
<th>Element</th>
<th>CO₂</th>
<th>CO</th>
<th>CH₄</th>
<th>C₂H₆</th>
<th>H₂</th>
<th>Unreacted</th>
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<tr>
<td>C*</td>
<td>0.4</td>
<td>3</td>
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<td>7</td>
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<td>83</td>
</tr>
<tr>
<td>H*</td>
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<td></td>
<td>26</td>
<td>14</td>
<td>37</td>
<td>23</td>
</tr>
<tr>
<td>C**</td>
<td>4</td>
<td>36</td>
<td>29</td>
<td>2</td>
<td></td>
<td>29</td>
</tr>
<tr>
<td>H**</td>
<td></td>
<td></td>
<td>29</td>
<td>8</td>
<td>62</td>
<td>1</td>
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</tbody>
</table>

* in only waste tire system  
** in waste tire/ZnO system

REFERENCES