Influences of the Constituents on Thermal Treatment of Rubberwood

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1. Introduction

In Southeast Asia Countries, various forms of residues are discharged from the rubberwood furniture parts process. In this process, a portion of wood residues are being thrown away to isolated country site and are burned illegally. These disposal methods do cause environmental problems, such as accidental forest burning, release of hazardous gases, and soil contamination by toxic preservatives. Besides, the issue of wood preservative has been paid attention. These problems are considerably serious in these countries.

Wood can be thermally decomposed into useful materials such as pyroligneous acid, char, and fuel off-gas. Off-gas contains several flammable gases such as, H_2, CO, CH_4. Pyroligneous acid and char from wood can be used as a wood preservative and an adsorbent respectively. Lim[5,6] and Konishi[7] proposed an improved rubberwood process as shown in **Figure 1.1**. In this process, pyroligneous acid obtained from the residue was employed as an alternative to the ordinary toxic preservative of the wood and alternative to the ordinary toxic preservative of the wood and the wastewater containing toxic compounds derived from pyroligeous acid was treated by adsorption capacity of the charcoal or activated carbon from the residue to solve the above problems. The fuel off-gas are recycled to the process.

In this study, constituent substances of rubberwood: lignin, cellulose, hemi-cellulose, were thermally treated and these results were compared with those of real rubberwood.

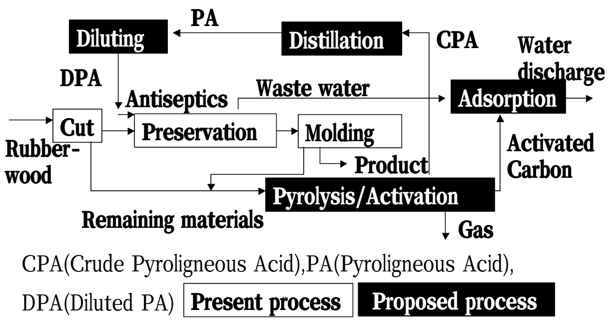

Figure 1.1 Schematic diagram of rubberwood processs

2. Experimental

2.1 Thermogravimetric analysis

Lignin, cellulose, and hemicellulose (xylan) were selected as principal constituents of rubberwood. Lignin is a three-dimensional polymer. It forms from 18 to 35 wt% of the dry wood, depending on the wood species. Cellulose is the main component representing 40 to 55 wt% of wood. Xylan is the predominant hemicellulosic compound in all hardwoods and forms from 20 to 35 wt% of the dry wood.

Lignin, cellulose, xylan, and rubberwood sawdust were grinded to 250 μm prior to the experiments. Thermogravimetric (TG) analysis was conducted using TG8120 thermobalance. The analyses were carried out under inert helium atmosphere with a constant flow rate of 0.006 m^3/h. Ten milligram of sample was filled in platinum crucible. The heating rate of TG was fixed at 22 °C·min^{-1}. The maximum heating temperature was 850 °C.

2.2 Thermal treatment

The apparatus of thermal treatment is shown in **Figure 2.1**.Lignin, cellulose, xylan, or sawdust of real rubberwood was thermally treated in the range from 673 K to 1,273 K in steam (H_2O) atmosphere. The experimental runs started from room temperature. Until 423 K, nitrogen (N_2, 0.0042 m^3/h) was supplied to sweep air out of the reactor. After 423 K, H_2O (0.03 m^3/h) was provided and the flow rate of N_2 was lowered to 0.0012 m^3/h, which was used as a tracer to know the flow rate of generated off-gas at the exit. The furnace was switched off at 30 min after reaching the treatment temperature. The crude pyroligneous acids (CPA) were collected by condensation of effluent gases.

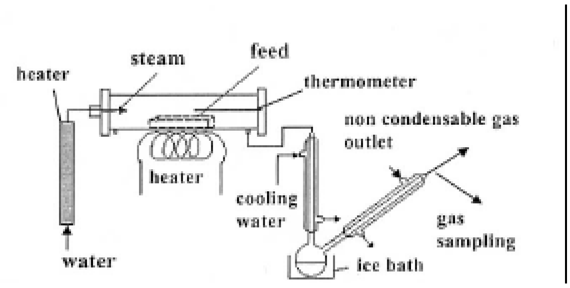

Figure 2.1 Schematic diagram of experimental apparatus for pyrolysis

3. Results and Discussion

3.1 Thermogravimetric Analysis

Figure 3.1(a)-(d) shows TG curves of lignin, cellulose, xylan, and rubberwood. About 40 % of lignin decomposed in the temperature range below 800 °C, and lignin would probably decompose greatly at higher temperature. Cellulose hardly decomposed below 300 °C and obvious change was observed in the range from 300 °C to 400 °C. Below 600 °C, the decomposition of cellulose was almost completed. In the range from 200 °C to 300 °C, xylan decomposed rapidly and kept on decomposing up to 700 °C. About 90 % of xylan finally decomposed. Below 250 °C, rubberwood decomposed only slightly. About 60 % of the rubberwood was decomposed from 250 °C to 350 °C. Between 350 and 800, about 10% the rubberwood decomposed.

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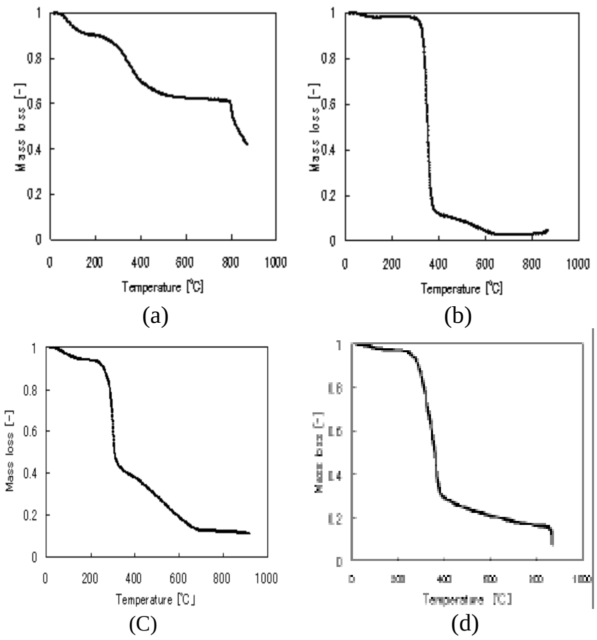

Figure 3.1TG curves: (a) lignin; (b) cellulose; (c) xylan; (d) rubberwood

3.2 Thermal treatment

The yield of product *i* (*i*=off-gas, flammable off-gas, char, crude PA, phenolic compounds in CPA) in the thermal treatment was expressed as,

$Y_i = W_i / W_{wood}$ (1)

where W_i is mass of the product and W_{wood} is that of the original rubberwood sawdust by dry basis.

H_2, CH_4, CO, and CO_2 were studied as components in off-gas. **Figure 3.2** shows the effect of thermal treatment temperature on the total yield of these four components, $Y_{off\text{-}gas}$. The yield of the off-gas increased with temperature in all cases. The yield in the case of lignin was higher, especially in the range of higher temperature. The total yields of flammable components in off-gas (H_2, CH_4, and CO) $Y_{flm.\ off\text{-}gas}$, is given in **Figure 3.3**. In all cases, while the yield of the flammable off-gas was quite low, that increased with temperature. It is attributed to the following reactions with H_2O in the range of higher temperature, which produces the flammable components much more than in low temperature range:

C (*s*) + H_2O (*g*) ? H_2 (*g*)＋CO (*g*) (2)

CO (*g*) + H_2O (*g*) ? H_2 (*g*)＋CO_2 (*g*) (3)

The yield of the flammable off-gas in the case of lignin was also higher in the range of higher temperature.

The yield of char, Y_{char}, is presented in **Figure 3.4**. Yield of char decreased with increasing temperature in all cases. This results from the reactions of carbon with steam, such as Eq.(2), which is active in higher temperature range. The yield increased in the order of cellulose, xylan, and lignin. Lignin was difficult to be decomposed, probably because of its complicated structure. The yield from rubberwood lay between those from cellulose and xylan. At low temperature, such as 400 °C and 600 °C yields of char got from thermal treatment were consist with the data that could be read from TG curves. At high temperature yield of char got from thermal treatment was somewhat smaller than that could be read from TG curves because of the reaction of char and steam.

Figure 3.5 provides the yield of crude PA (CPA), Y_{CPA}. The yield of CPA decreased with temperature. The yield from cellulose was highest and that from lignin was lowest. The yield from rubberwood was higher than that from lignin and was lower than that from xylan. **Figure 3.6** shows the total yield of phenolic compounds in CPA. Not much difference was between cellulose and xylan at any temperature. Lignin produced more phenolic compounds comparing to cellulose and xylan in all cases.

4. Conclusion

The thermal behavior of the main constituent materials in steam atmosphere became clearly.

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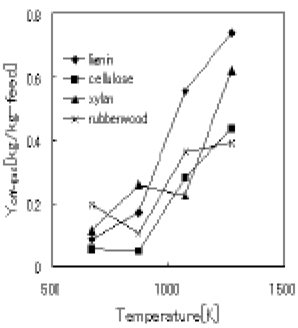

Figure 3.2 Yield of off-gas

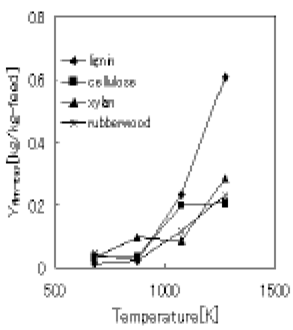

Figure 3.3 Yield of flammable off-gas

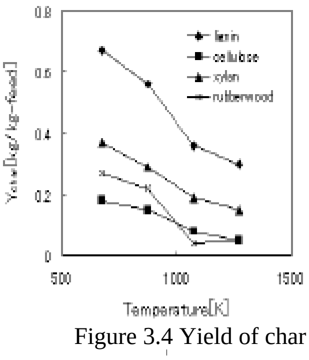

Figure 3.4 Yield of char

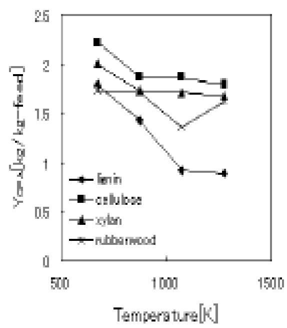

Figure 3.5 Yield of CPA

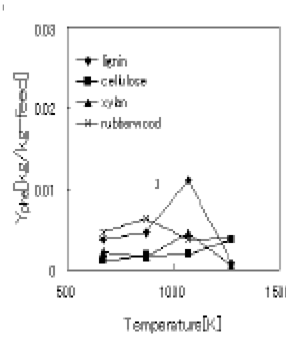

Figure 3.6 Yield of phenolic compounds in CPA