Production of Pyroligneous Acid and Charcoal by Thermal Treatment of Rubberwood using Steam Atmosphere

SHI NAN
Student ID : 03-1185-2
Supervisor: EGASHIRA RYUICHI
Department of International Development Engineering, School of Engineering, Tokyo Institute of Technology, Tokyo 152-8552, Japan

Introduction

In Southeast Asia, there are many problems concerning the discharge from rubberwood furniture manufacturing process. Among the problems are large quantity of the rubberwood residues and the toxic substances used for wood preservation. The wood residues and the toxic preservatives discharged from the process impact the environment, polute the soil and the river.

To counter these problems, the thermal treatment of rubberwood and the effectual utilization of the products from the process were studied[1,2]. In previous works, the products namely pyroligneous acid, charcoal, and off-gas are used as an alternative to the ordinary toxic preservative, an adsorbent to remove the preservative from the wastewater, and a heat source for these addition operations, respectively, within the process.

In this study, rubberwood was thermally treated using steam atmosphere to produce pyroligneous acid and charcoal. The yields of these products, constituents and composition in the pyroligneous acid, surface morphology and adsorption performance of the charcoal were studied under various conditions.

1. Experimental

The feed raw material was the sawdust of rubberwood from Malaysia.

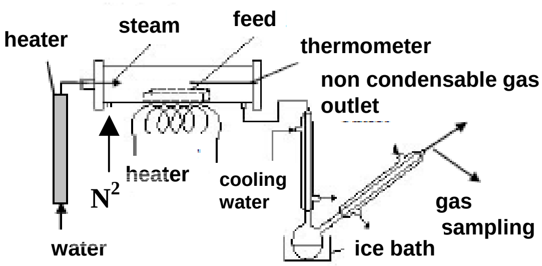

Fig.1 Apparatus of thermal treatment

The apparatus of thermal treatment is shown in Figure1. The raw materials was treated in a stainless steel tube (I.D. 0.0384 m × 0.70 m) heated by a commercial cylindrical electric furnace under steam atmosphere in order to obtain the charcoal and the crude pyroligneous acid (CPA). The carbonizations were carried out with 25 to 30 g of the feed sawdust in the temperature range of 400 to 800 °C for 1hr after reaching respective temperature. The heating rate from room temperature to thermal treatment temperature was about 0.36 °C/min.The flow rates of the steam were fixed at 0.5 l/min(s.t.p.) in all runs.

The crude pyroligneous acids (CPA) were collected by the condensation of effluent gases. Tar fraction was removed from CPA by simple distillation up to 140 °C to obtain pure pyroligneous acid (PA). The chemical composition and the moisture of the PA were analyzed by a gas chromatograph and a Karl-Fischer titrator, respectively.

The charcoals made from the sawdust were washed with boiling water, and dried. The phenols in aqueous solutions were adsorbed by the charcoal. 0.1 g of adsorbents and 0.025 l of feed solution were added in a conical flask 0.1 l .The flask was shaken at room temperature (22 ± 1 °C) with shaking velocity of 90 min^{-1} for 3 to 5 days.

2 Results and discussion

2.1 Yields of charcoal, CPA and PA

Figure 2 shows the yield of the charcoal, CPA and PA. The yield of charcoal decreased as the thermal treatment temperature increased. The yield of CPA and PA were increased at 400～500 °C and declined over 600 °C.

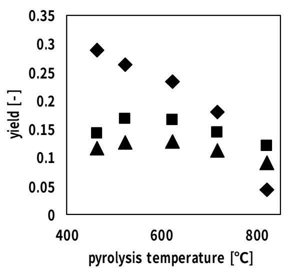

Fig.2 Yields of charcoal, PA and CPA
◆−Charcoal, ■− CPA, ▲−PA

The chemical compounds in PA were shown in Figure3. The concentration of guaiacol in PA was higher than the other compounds. The same trend was reported from previous study[4]. The concentration of guaiacol decreased with treatment thermal treatment temperature. But the concentration of other compounds was low and unchanged.

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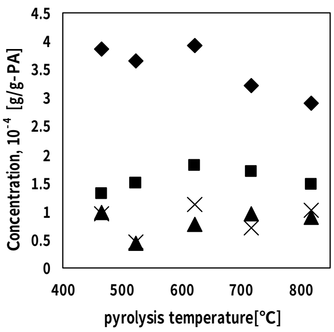
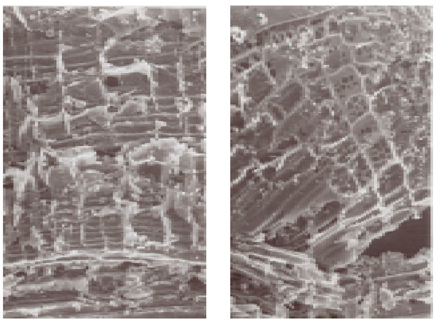


Fig.3 The concentration of the phenols in PA
◆- Guaiacol, ■- Phenol, ▲- m,p-Cresol,
×- Syringol

2.2 Charcoal characterization

2.2.1. Scanning Electron Microscope (SEM)

The surface morphology of charcoals at different temperature was observed with a Scanning Electron Microscope (SEM). The photos of the steam atmosphere charcoal (SC) in 400 °C and 700 °C are shown in Figure 4. The pictures show the difference of the porous surface among the charcoals at different thermal treatment temperature. At 700 °C the pores can be seen developed on the surface but at 400 °C the pores were not detected.



SC400 SC700

Fig.4 SEM images for steam environment charcoal SC 400 and SC700

2.2.2 Adsorption of the phenols

Aqueous solutions of chemical components in PA, namely phenol, syringol and guaiacol were used for adsorption experiments. The adsorption experiment using charcoal at 800°C was not performed because the yield was too low. Figures 5 and 6 show the adsorption isotherms of phenols. The adsorptions of phenols were increased with thermal treatment temperature. This may result from the porosity of charcoal at higher temperature. Figure 5 is the comparison of adsorption of phenols using charcoals at different conditions. The sequence of adsorption is AC800>SC700 1 hr>SC800 0.5 hr>SC600 1 hr>SC500 1 hr. The highest adsorption, AC800 was prepared under N_2 atmosphere and further activated by CO_2.

Table 1 shows the comparison of chars at different conditions. The last column of q_{ph} ×Y-char is the performance of charcoals according to the adsorptions of phenols and the yield. SC600 1 hr shows the highest value indicates that the best condition to prepare the adsorbent is under steam atmosphere 600 °C at 1 hr holding time.

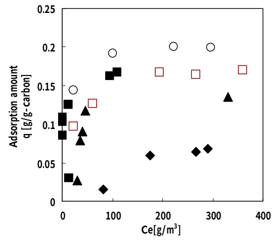


Fig.5 Adsorption isotherms of phenol
○- AC800, ■-SC700 1hr, □－SC800 0.5hr,
▲-SC600 1hr, ◆-SC500

Table 1 The comparisons of adsorption property of charcoals at the different conditions

Name	Atmosphere	Temperature [°C]	Hold time [hr]	q_{ph} [g/g-carbon]	Y-Char	q_{ph}×Yield
AC800 [2]	N2-CO2	600-800	0.5	0.2	0.148	0.0296
C600 [2]	N2	600	0.5	0.07	0.2	0.014
SC700	Steam	700	1	0.17	0.18	0.0306
SC600	Steam	600	1	0.14	0.23	0.0322
SC500	Steam	500	1	0.06	0.24	0.0144
SC400	Steam	400	1	0.05	0.29	0.0145
SC800 [3]	Steam	800	0.5	0.17	0.1	0.017
SC600 [3]	Steam	600	0.5	0.12	0.21	0.0252

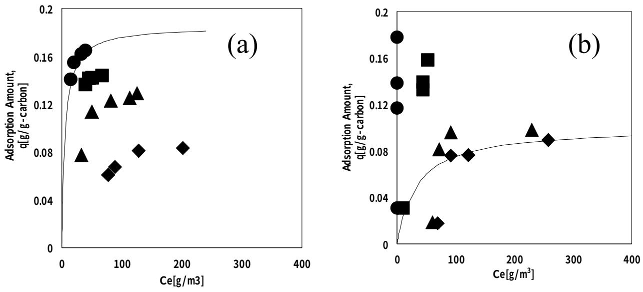


Fig.6 Adsorption isotherms. (a) syringol (b) guaiacol
●- SC700, ■- SC600, ▲–SC500, ◆- SC400

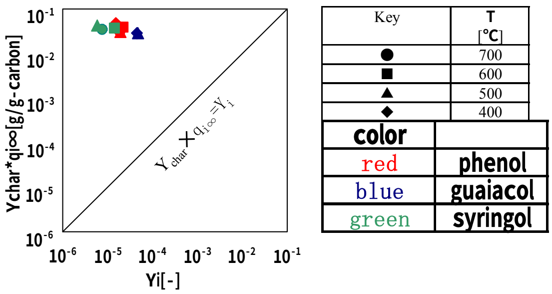


Fig.7 The comparison of the yields of PA components and the adsorption amount of the chars

Figure 7 show the comparison of the yield of PA components and the adsorption amount of the chars. Charcoals produced from thermal treatment of each temperature had quite higher adsorption capacity than the amount of PA components.

Conclusion

Charcoal and pyroligneous acid were successfully produced from thermal treatment of rubberwood under steam atmosphere. Charcoal had enough adsorption capacity for PA.

Reference

[1] K.Lim.; Mater Thesis, Tokyo Tech, 2004
[2] S.Konishi; Bachelor Thesis, Tokyo Tech, 2004
[3] M.Sato; Bachelor Thesis, Tokyo Tech, 2005
[4] S.Qi; Bachelor Thesis, Tokyo Tech,2006