Heat Treatment of Rubberwood Residue in Steam Atmosphere

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1. Introduction

In Southeast Asian countries, furniture parts made of rubberwood are ones of the important products for exportation. Nowadays, there are two problems in the rubberwood process, a large amount of rubberwood residue and the use of toxic substances for wood preservation. In Malaysia, about 4×10^5 ton/year of rubberwood residues were evolved[1].

Wood can be precursor of various kinds of useful chemical substances, *e.g.*, fuel offgas, pyroligneous acid, activated carbon. Pyroligneous acid and activated carbon are widely used as a wood preservative and an adsorbent, respectively. Lim[1,2] and Konishi[3] proposed an improved rubberwood process as shown in **Fig.1**. In this process, pyroligneous acid obtained from the residue was employed as an alternative to the ordinary toxic preservative of the wood and the wastewater containing toxic compounds derived from pyroligneous acid was treated by adsorption using charcoal or activated carbon from the residue to solve the above problems. However, the adsorption capacity of the charcoal was relatively low and the preparation of the activated carbon was not so convenient because of the activation with carbon dioxide separately from the carbonization. Heat treatment in steam atmosphere is well known as a method to make activated carbon from wood[4,5].

In this study, rubberwood was treated by heat under steam atmosphere to give pyroligneous acid, activated carbon, etc., and these products were characterized in terms of yield, composition, adsorption properties, and so forth.

2. Experimental

The apparatus used for heat treatment is shown in **Fig.2**. Sawdust of rubberwood (*Heavea brasiliensis*) was treated in a stainless steel tube (I.D. 0.0384 m×0.70 m) heated by a commercial cylindrical electric furnace under a H_2O steam atmosphere to obtain the crude pyroligneous acid and activated carbon (SC). The heating rate from room temperature to specified treatment temperature was about 0.36 °C/min. The furnace was switched off at 30 min after reaching the treatment temperature and the flow rate of the steam were fixed at 0.5 *l*/min (s.t.p.) or 0.4 m*l*/min. (water) in all runs.

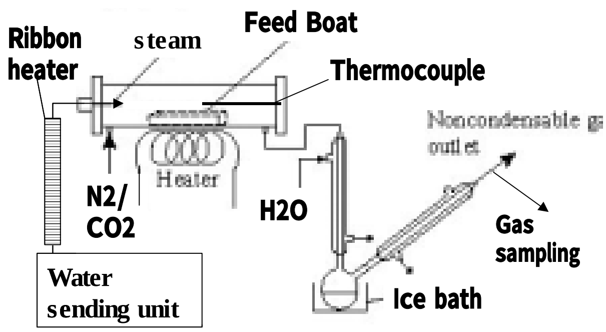

Fig.2 Experimental equipment

The crude pyroligneous acids (CPA) were collected by condensation of effluent gases. The temperature of the treatment (carbonization and activation) were varied in the range of 300~1,000 °C. Tar fraction was removed from CPA by simple distillation up to 140 °C in order to obtain pure pyroligneous acid (PA). The activated carbons prepared by the treatment of the sawdusts were washed with boiling water, dried, ground, and were screened into 36~100 mesh.

The original, diluted pyroligneous acids obtained above, and model aqueous solutions of phenol were brought into contact with the activated carbons to be attained to adsorption equilibria.

CPA, PA, and model solutions were analyzed by GC and Karl Fischer titrator to know the concentrations of phenolic compounds, acetic acid, water, and so on.

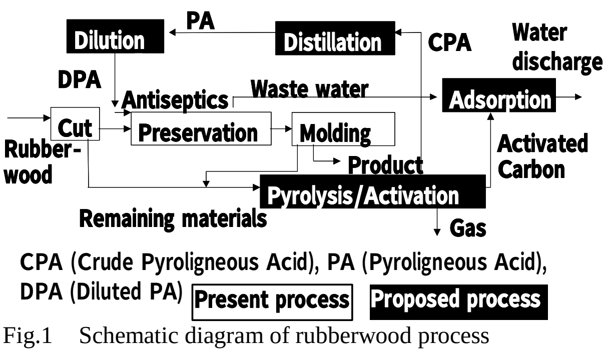

Fig.1 Schematic diagram of rubberwood process

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3. Results and Discussion

3.1. Heat treatment of rubberwood and pyroligneous acid

The fractional yields of the products of heat treatment relative to the sawdust feed are shown in **Fig.3** together with the previous results with N_2 atmospheres. The yields of activated carbon or charcoal, CPA, and non-condensable gas were almost equivalent between with steam and N_2, in the range of reaction temperature lower than about 600 °C. At the reaction temperature over 600 °C, the yields of activated carbon and gas with steam were lower and higher, respectively, than those of charcoal and gas with N_2. Activation with CO_2 also decreased the mass of the chars.

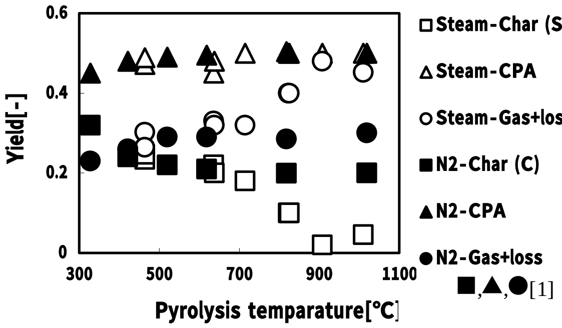

Fig.3 Yields of products (comparison with N_2 atmosphere)

The concentrations and fractional yields relative to the feed sawdust of studied compounds in the pyroligneous acid are summarized in **Table 1**. Phenolic compounds (guaiacol, cresol, phenol, syringol) are effective for preservation. The components but water and their fractional yields in CPA obtained with steam were almost same as those with N_2. The previous antifungus and preservation tests of the PA obtained by N_2 pyrolysis (PA-N_2) proved that PA-N_2 could preserve rubberwood[1]. PA obtained with steam atmosphere in this study would be used as wood preservatives as well.

3.2. Adsorption by activated carbon from rubberwood

Figure 4 gives the adsorption isotherms of phenol by the activated carbon in the case of the model solution. The activated carbon prepared with steam atmosphere could adsorb phenol favorably. The adsorption amount of phenol increased

Table 1 Concentrations and fractional yields relative to feed sawdust of studied compounds in pyroligneous acid

	Concentration[g/g-CPA]		Yield[g/g-feed(dry)]	
	PA-N2	PA-steam	PA-N2	PA-steam
Methanol	0.04250	0.01960	0.01221	0.01143
Acetic acid	0.08640	0.05933	0.04162	0.03460
water	0.65270	0.85000	0.18130	-
Guaiacol	0.00170	0.00114	0.00041	0.00067
Phenol	0.00020	0.00033	-	0.00019
o-Cresol	0.00003	-	-	-
m-Cresol	0.00010	0.00005	0.00001	0.00003
p-Cresol	0.00010	0.00006	0.00001	0.00004
Syringol	0.00020	0.00028	0.00004	0.00016

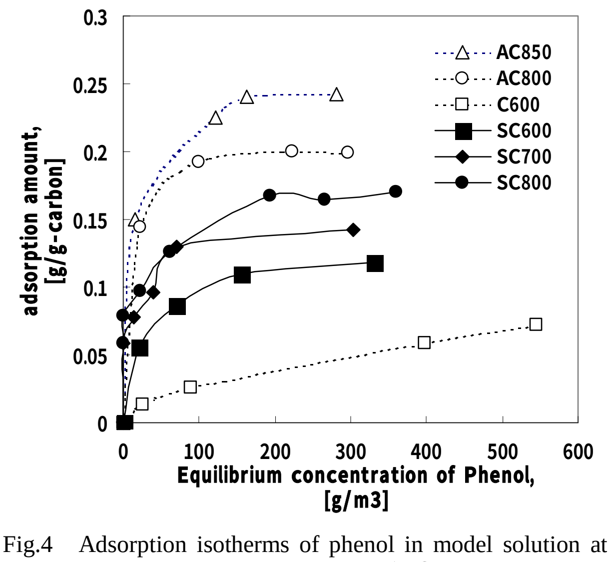

Fig.4 Adsorption isotherms of phenol in model solution at 30 °C on the different carbons (△,○,□[3])

with increasing temperature of heat treatment. The previous results of charcoal, C, and activated carbon made with N_2 and CO_2 atmospheres, AC, are also shown in Fig.4[3]. The adsorption capacities of activated carbon in this study were somewhat smaller than those of the carbon activated by CO_2 but much higher than that of charcoal.

Table 2 shows the comparison of chars from some conditions. The product of the adsorption amount and the fractional yield corresponds to the amount adsorbed per unit

Table 2 Comparison of condition of producing chars

name	atmosphere	step	temperature [°C]	Char A.P.	Char Yield	A.P.×Yield
C600	N2	1	600	0.07	0.2	0.014
AC800	N2-CO2	2	600 & 800	0.2	0.148	0.0296
SC800	Steam	1	800	0.17	0.1	0.017
SC700	Steam	1	700	0.14	0.18	0.0252
SC600	Steam	1	600	0.12	0.21	0.0252

* A.P.: Adsorption amount of phenol [g/g-carbon], C600 and AC800 are from [3]

mass of the feed rubberwood sawdust. In terms of this factor, AC and SC were comparable and were superior to C. On the other hand, C and SC can be obtained by only single reaction step, while two steps are required to give AC. Moreover, it is more convenient to prepare steam than carbon dioxide. Consequently, heat treatment with steam atmosphere would be an appropriate way to convert rubberwood residue in the process.

4. Conclusion

Heat treatment of rubberwood could make the pyroligneous acid, which could be used as a wood preservative, and the activated carbon, which could adsorb toxic compounds contained in the pyroligneous acid. This would improve the rubberwood process.

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