Heat Recovery from Off-gas in Thermal Treatment of Rubberwood Residues

Student Number: 05-23324 Name: MITANI Saori Supervisor: EGASHIRA Ryuichi

Introduction

In Southeast Asian countries, rubberwood furniture manufacturing is an important industry. Sawmilling provides the processed wood for the industry. Fig. 1 shows the current sawmilling process[1]. The problems from the process are a large amount of wood residue, toxic preservatives, and wastewater containing the preservatives. They cause environmental pollution.

To improve this manufacturing process, the utilization of products from thermal treatment of rubberwood residue is proposed. Pyroligneous acid can be used as preservative, activated carbon as adsorbent to adsorb toxic substances in the pyroligneous acid, and off-gas as the heat energy[2].

In this study, rubberwood was thermally treated under steam atmosphere. Yields and characteristics of products i.e.off-gas, activated carbon and pyroligneous acid were studied under various conditions. The off-gas was evaluated to be utilized as heat energy. The possibility of the proposed process was discussed.

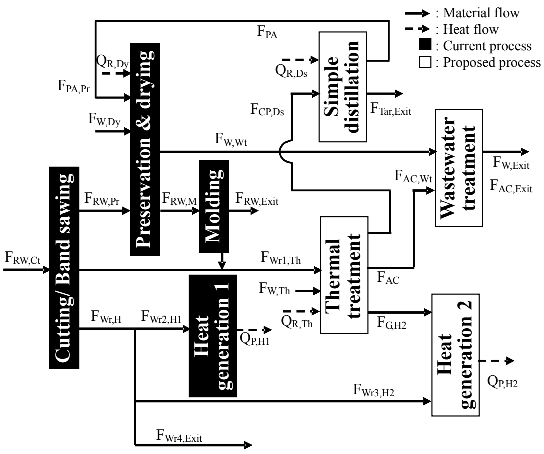

Fig.1 Current and proposed process of sawmilling: material and heat flow

1. Thermal Treatment of Rubberwood

1.1 Experimental

The material is rubberwood sawdust (RW) from manufacturing company in Malaysia. It was kept in desiccator for at least a day to dry.

The experimental equipment is as stated in previous study[1]. The RW was treated in a stainless steel tube (I.D. 0.0384 m × 0.70 m) heated by a commercial cylindrical electric furnace under various conditions to obtain the off-gas, activated carbon(AC), crude pyroligneous acid (CPA). The heating rate from room temperature to specified treatment temperature was about 0.4 ℃ / min. The furnace was turned off at 0.5 h~2.0 h after reaching the treatment temperature and the flow rate of the steam were fixed at 0.5 l / min (s.t.p) on all runs. The treatment temperature was varied in the range of 679 K~1079 K.

Samples of the off-gas were taken at the exit of the apparatus along time, until the furnace cooled down to 313~323 K. The gas samples were analyzed by gas chromatograph with TCD to know the compositions and flow rates and yields of the respective gas components were calculated by comparison with the flow rate of N_2.

Elementary analysis of AC and RW were conducted by CHN coder MT-6.

The CPA was collected by the condensation of effluent gases. CPA was purified into pyroligneous acid (PA) by simple distillation up to 413 K. The moisture contents in CPA and PA were determined by Karl-Fischer titrator and the chemical composition of PA was determined by gas chromatograph with FID.

1.2 Results and discussion

1.2-1 Yield of off-gas, AC, CPA, and PA

Fig. 2 shows the yield of each product of thermal treatment together with the previous data[2]. They are almost at the same value with the previous ones. The yields of off-gas and AC increased and decreased respectively with treatment temperature. The changes between 897 K and 1097 K were sharp.

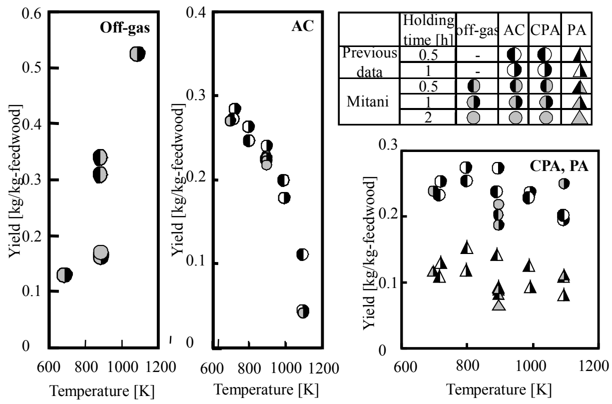

Fig.2 Yield of thermal treatment product

1.2-2 Characterization of off-gas

The composition and yield of the component of off-gas are shown in Fig. 3. Low heating value (LHV) of off-gas are also plotted. It increased with treatment temperature. The amount of hydrogen and carbon dioxide gases suddenly increased from 897 K to 1097 K because the water gas shift reaction as in the following equation took place [3]:

$$CO + H_2O \rightarrow CO_2 + H_2$$

The holding time has no significant effect on the production. The production of gas took place mainly in first one hour. 1 h holding time was thus, enough to obtain the off-gas for heat energy from RW.

1.2-3 Heat recovery from products of thermal treatment

The required heat in the thermal treatment was estimated from the enthalpy of inlet and outlet materials. The enthalpy of the inlet materials, RW and water, were calculated at room temperature and that of the outlet, off-gas, AC and CPA, were calculated at the thermal treatment temperature of each run. The required heat in the simple distillation was estimated from the enthalpy of inlet material, CPA, calculated at room temperature, and outlet materials, PA and tar, calculated at the distillation temperature. Total required heat is the synthesis of these heats. Heat recovery of off-gas is the low heating value of the off-gas over total required heat and is shown in Fig. 4. It increases with treatment temperature. In contrast, holding time has no significant effect on heat recovery.

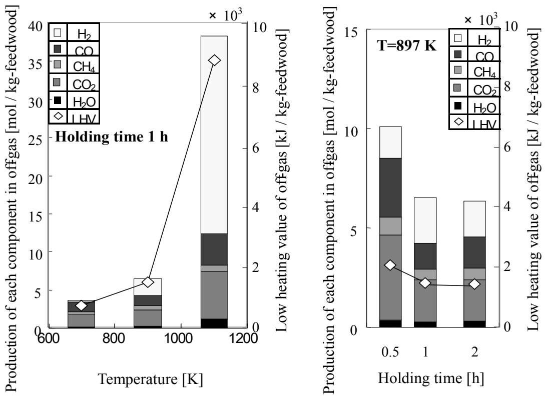

Fig. 3 Production of component of off-gas

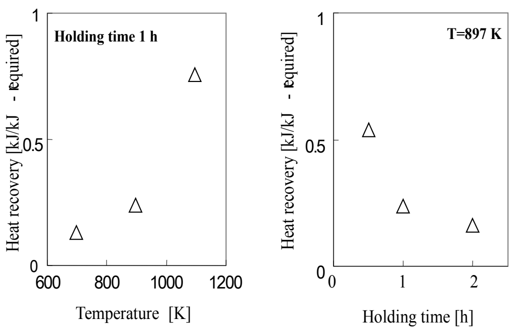

Fig.4 Heat recovery of off-gas

2. Process improvement

According to the above results, we proposed to improve the process as illustrated in Fig.1. A portion of residues from cutting and molding are thermally treated under steam atmosphere to produce the CPA, AC and off-gas. The CPA is distilled to PA to be used as preservative, replacing the current toxic preservative. The wastewater from the preservation and drying process which contains the phenolic compounds in the PA is treated by the AC. The remaining wood residues and off-gas are used for heat generation.

Now, we changed the ratio of residue from rubberwood feed for thermal treatment, and calculated each flow rate, when the required heat of whole process is equivalent value to the produced heat of whole process. The required heat of whole process was the synthesis the heat of drying, thermal treatment and simple distillation. The produced heat of whole process was the synthesis the low heating value of off-gas and wood residue which are not used for thermal treatment.

Two cases were assumed. In Case 1, the whole feed were used for thermal treatment or burning. In Case 2, the minimum amount of wood residue was thermally treated to obtain the required amount of AC for wastewater treatment. AC and PA were remained in Case 1. Wood residue and PA were remained in Case 2. The required amount of PA for preservation was obtained in both case.

Fig 5 shows the fractional heat recovery. At all the temperature, heat recovery from off-gas in Case 2 is higher than Case 2. It indicates that smaller amount of residue for thermal treatment is required in Case 2.

In Case 1, heat recovery from off-gas is increase with temperature. It was because the production of off-gas increased with treatment temperature. In Case 2, it is smallest at 897 K. At low treatment temperature, it is high because large amount of AC is needed due to low adsorption capacity of the AC[4]. At higher temperature, it also becomes high because of lower AC yield, so we need to thermally treat high amount of residues.

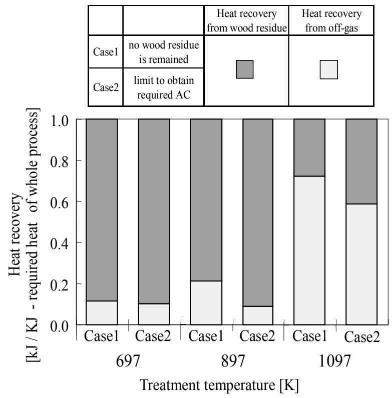

Fig.5 Fractional heat recovery

Conclusion

The effect of thermal treatment condition on characteristics of products was measured. The yield of products change with treatment temperature, but not eith holding time. Off-gas has enough heating value for heat generation and we can obtain sufficient heat recovery at high temperature.

In the proposed process, some amount of heat recovery from off-gas was possible. It would give the possibility of improving the existing process.

Literature Cited

[1]-Rizafizah Othaman, Kean Giap Lim, Shunsuke Konishi, Ma sayuki Sato,Nan Shi and Ryuichi Egashira "Thermal treatment of wood residues and effective utilization of its products to improve rubberwood manufacturing process", Journal of Chemical Engineering of Japan, Vol.41, No.12, pp. 1149-1158, 2008

[2]-K.G. Lim, Master Thesis, Tokyo Institute of Technology, 2004

[3]-J.M. Encinar, J.F. Gonz´alez, J. Gonza´lez : " Steam gasification of *Cynara cardunculus* L.:influence of variables" , Fuel Processing Technology Vol.75 2002 , p.27–43

[4]-Konishi Shunsuke, Master Thesis, Tokyo Institute of Technology, 2006