

Utilization of Bio-oil Derived from Wood Residues in Rubberwood Process

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1. Introduction

Rubberwood furniture manufacturing is an important industry in Southeast Asian countries, and the sawmilling process has been studied to be improved by the utilization of wood residue, as shown Fig.1 [1]. The operations expressed by white-colored boxes were additional ones to be proposed. The products from the thermal treatment of the wood residue, such as pyrolygneous acid, activated carbon, and off-gas, were used as preservatives, adsorbent, and heat energy. However the utilization of bio-oil has not been studied.

In this study, rubberwood sawdust was thermally treated, and the yields and characteristics of the bio-oil obtained under various conditions were examined. Then, utilization of the bio-oil as heat source in the process was studied.

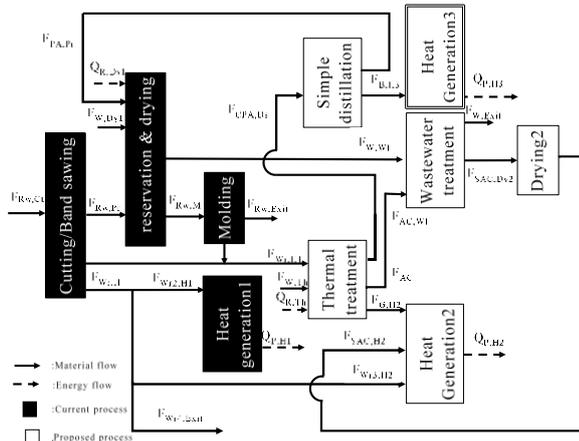


Fig.1 Current and proposed process of sawmilling: material and energy flow[1]

2. Thermal treatment of rubberwood

2.1 Experimental

The rubberwood sawdust (RW), provided from manufacturing company in Malaysia, was used as pyrolysis feed.

The experimental equipment is as stated in previous study [1]. Table 1 shows the conditions of thermal treatment. The RW was dried at 373 K for 24 hours before the treatment. The dried RW was heated by a commercial electric furnace under nitrogen atmosphere in a stainless tube (I.D. 0.0384 m × 0.70 m) and pyrolyzed to crude pyrolygneous acid (CPA), char and off-gas. The sample of off-gas were taken at the exit of apparatus along time, until the furnace cooled down to 313K.

The CPA was collected by the condensation of the effluent gas. CPA was separated into pyrolygneous acid (PA) and bio-oil by simple distillation. The final temperature of the liquid was varied from 393 K to 433 K. The obtained CPA, PA and bio-oil were analyzed to determine the moisture content and pH by Karl Fischer

titrator and pH meter, respectively. The elemental analysis of bio-oil were conducted by MICRO CORDER JM10.

Table 1 principal conditions for thermal treatment

Feed	rubberwood sawdust	
Mass of feed	[kg]	0.020-0.030
Atmosphere		N ₂
Flow rate	[L/min]	0.5
Temperature	[K]	713, 903, 1093
Holding time	[hour]	0.5
Ice bath temperature	[K]	275-278

2.2 Result and discussion

The yield of CPA, Char and Off-gas based on the RW, and those of PA and bio-oil based on the feed CPA were defined as,

$$Y_i = \frac{W_i}{W_{RW}} \quad (1)$$

where W_{RW} and W_i were the mass of the feed RW and product i ($i = \text{CPA, Char, or Off-gas}$). $Y_{\text{Off-gas}}$ was estimated by material balance.

Fig.2 showed the yield of CPA, Char, and Off-gas of thermal treatment of RW together with previous data in dried condition [2]. T_T was temperature of thermal treatment and T_S was the final temperature of the liquid. The yield of CPA and Off-gas gradually increased with T_T , and the yield of Char decreased as T_T decreased. Although these trends were the same as the previous data, the yield of CPA of this study was a little higher than those in the previous study.

Fig.3 showed the yield of PA and bio-oil. The yield of bio-oil increased as T_T increased and T_S decreased. The higher T_T enhanced yield of CPA and heavier compounds should be generated more in the higher T_T range.

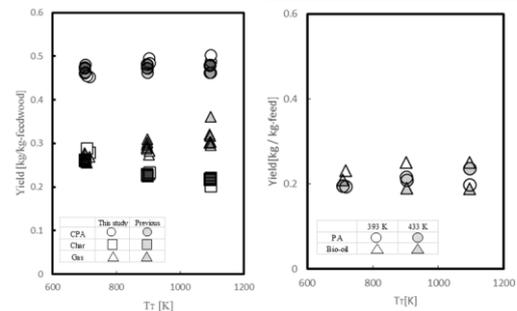


Fig.2 Yield of each component in thermal treatment Fig.3 Yield of each component in simple distillation

Fig.4 showed pH of CPA, PA, and bio-oil and Fig.5 showed moisture content of them. Bio-oil had no moisture content, and pH of each bio-oil was almost constant to be 2.1. Moisture content of CPA was 0.40 and pH of CPA was in the range from 1.9 to 2.4.

Moisture content of PA was 0.70 and pH of CPA was the range from 2.1 to 2.3.

Table2 also showed characterization of bio-oil. The element of composition in bio-oil was almost constant independently of condition.

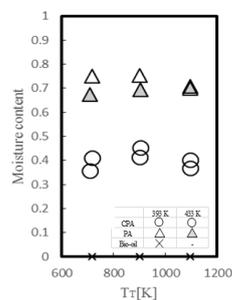
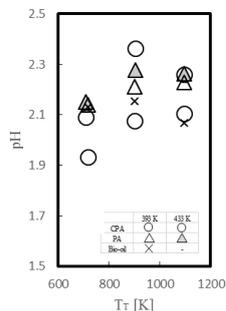


Fig.4 pH of CPA, PA, Bio-oil **Fig.5** Moisture content of CPA, PA Bio-oil

Table2.Result of elementary analysis

Tr[K]	Ts[K]	H	C	N	O
713	393	0.059	0.485	0.001	0.398
903	393	0.061	0.507	0.001	0.402
1093	393	0.062	0.502	0.000	0.414
713	403	0.062	0.545	0.001	0.385
903	403	0.062	0.539	0.001	0.387
1093	403	0.062	0.530	0.000	0.398

3. Heat recovery from bio-oil

3.1 Determination of heating value of bio-oil

The empirical equation estimate higher heating value, HHV, of bio-oil derived was reported as [4],

$$\text{HHV} = 35.2x_C + 99.4x_H + 10.5(x_S - x_O) \quad (3)$$

where x_i was the mass fraction of element i in the bio-oil (i is C, H, S or O). Generally plants should contain S by so low level and it was assumed $x_S = 0$. Then, the HHV was estimated as 19.8 MJ / kg-bio-oil, and LHV was as 19.7 MJ /kg-bio-oil. Here it was assumed that all hydrogen be should be converted water and the latent heat was taken into consideration.

3.2 Process improvement

In **Fig.1**, $Q_{P,H1}$, $Q_{P,H2}$, $Q_{P,H2(\text{off-gas})}$, $Q_{R,Dy}$, $Q_{R,Dh}$ and $Q_{R,Ds}$ were estimated from the enthalpy of inlet and outlet materials. In thermal treatment, RW and water were the inlet materials at room temperature and AC, CPA, and off-gas were outlet materials at the thermal treatment temperature. In simple distillation, CPA was inlet material at room temperature and PA and bio-oil were outlet materials at the final temperature of simple distillation. Total heat required heat is the synthesis of these added heat of drying RW. This study was used previous data because of getting overall process and data for thermally treatment process [5]. $Q_{P,B}$ was estimated from Eq.(3). **Fig.1** showed was proposed to improve the process to use bio-oil. Bio-oil was used in Heat generation 3 I thought, I added new box on double line in **Fig.1**.

Now, it was 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. Under **Table3**, we calculated the case the whole feed were used for thermal treatment or burning with previous data [5]. In input material flow, $F_{AC,Wt}$ was not changed because absorbed amount of AC was not changed by doing bio-oil as a heat source. $F_{Wt,Th}$ was more amount than precious data because the amount of generated heat increased for doing bio-oil. So the amount of used RW residue in thermal treatment and result of heat recovery increased compared to previous data. In this result, bio-oil which we had thrown away had about 30 % on quantity of heat in each temperature and was shown to be beneficial.

Table3 Result of heat recovery

Temperature		[K]		697		897	
				Previous	This	Previous	This
Material flow	input	$F_{Wt,Th}$	[ton / year]	566	630	565	660
		$F_{AC,Wt}$	[ton / year]	69.2	69.2	8.10	8.10
	output	F_{AC}	[ton / year]	140	155	120	134
		F_{GH2}	[ton / year]	110	124	140	169
Energy flow	required	$Q_{R,Dy}$	$\times 10^6$ [kJ / year]	0.4			
		$Q_{R,Th} + Q_{R,Ds}$	$\times 10^6$ [kJ / year]	4.3	4.8	5.1	6.0
	produced	$Q_{P,H2}$	$\times 10^6$ [kJ / year]	4.3	3.5	5.1	4.0
		$Q_{P,B}$	$\times 10^9$ [kJ / year]	-	1.3	-	2.0
		$Q_{P,H1}$	$\times 10^6$ [kJ / year]	0.4			
		$\frac{Q_{P,H2(\text{off-gas})} + Q_{P,B}}{Q_{R,Dy} + Q_{R,Th} + Q_{R,Ds}}$		0.15	0.41	0.27	0.58

4. Conclusions

The effect of thermal treatment temperature and simple distillation temperature had little difference the elemental yield of bio-oil.

Bio-oil had much heating value so in this proposed process, the use of bio-oil was shown to be beneficial.

Acknowledgement

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