목재에 대한 유기용매의 비가 펄프의 카파수와 수율에 미치는 영향

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Effect of Liqour-to-Wood Ratio on Kappa No. and Yield of the Pulp

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Introduction

This paper dealt with a novel organosol type pulping process designed to minimize water consumption. As a representative hardwood, aspen was used as a pulp feedstock and monoethanolamine was employed as the pulping reagent. The prime goal in this study was to verify the effect of liquor-to-wood ratio on pulp quality and composition including Kappa number. The important finding was that delignification was not adversely affected by reduction of the liquor-to-wood ratio as long as it remained above two. The advantage of the low liquor-to-wood ratio was quantified in terms of solvent recovery. The results of this study indicate that the low-liquor amine pulping is a promising process for hardwood pulping.

The liquor-to-wood ratio in solvent pulping is an important factor in the economics of paper production. It is closely related with the solvent input, the energy requirement, and the equipment size required.

The ratio of liquor-to-wood in organic pulping depends upon the kind of solvent used. Table 1 shows representative liquor-to-wood ratios that have been applied in various organic pulping studies. It appears that with volatile solvents such as methanol and ethanol, it is necessary to use a high liquor-to-wood ratio, normally in the vicinity of 10:1 in order to maintain a solvent concentration in the liquid phase high enough to promote delignification. On the other hand, less volatile solvents such as amines and phenol can delignify the wood with lower liquor-to-wood ratios.

Table 1. Solvent Pulping of Aspen

Sovlent	% in water	wood:liquor	cooking T	Kappa/yield(wt%)	ref.
Ethanol	50	1:10	195	27-36/53-58	1
Metanol	50-100	1:10	130-220	8-19/59-63	2
ESTER		1:6	170	9-10/52-53	3
(Acetic Acid 33 % + Ethyl acetate 33 %)					
Sulpholane	50	1:6	130-160	26-39/52-55	4
M.E.A	50	1:1.9	186	13/61	-[a]

[a] This work

Experimental Methods

The experimental set-up for aspen chip cooking is shown in Figure 1. Pre-measured liquor (0.5 to 8.8 liquor-to- wood (% w/w) was mixed with aspen chips. The concentration of MEA in liquor ranged from 30 to 50% v/v. The wet chips were loaded into an autoclave (Parr Instruments). Cooking was carried out at a specified temperature for different cooking times under a nitrogen atmosphere. Upon completion of a run, the reactor was taken out of the heater assembly and quenched with tap water.

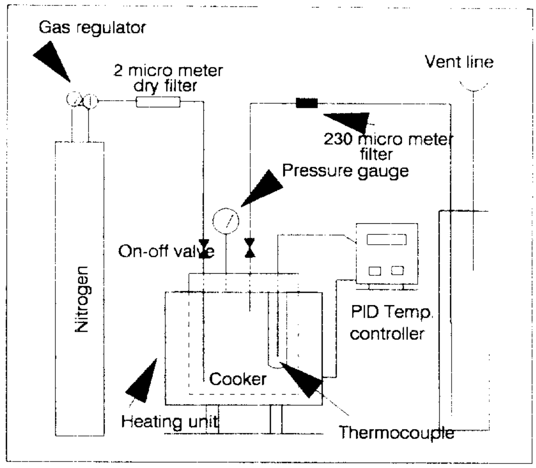

Figure 1. Low Liquor Pulping Apparatus

Results and Discussion

Low-liquor pulping

A series of separate cooking runs were made to determine the effect of the liquor-to-wood ratio on pulp yield and Kappa number. Different ratios of liquor- to-wood were used in each of these runs. The solids were analyzed for pulp yield and Kappa number. The results are pres- ented in Figure 2. A solid line indicates Kappa number vs. liquor-to-wood ratio, and a dotted line represents pulp yield vs. liquor-to-wood ratio. A sharp increase of the Kappa number was observed at the liquor-to-wood ratio of 1.9. From this it was concluded that delignification was inefficient when the liquor-to-wood ratio is less than 1.9. Above 1.9 the extent of delignification remained almost constant. This ratio is therefore termed as the saturation ratio, because this is the point at which no more liquid can be introduced into aspen chips. The dotted line shows that the yield decreases with an increasing liquor-to- wood ratio. A 60.5% yield at L/S = 1.9 and a 58% Yield at L/S = 8.8 were obtained.

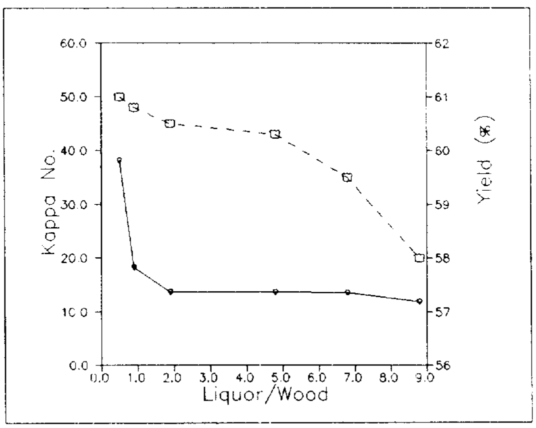

Figure 2. Effect of Liquor-to-Wood Ratio on Kappa Number and Yield

The difference in yield may be due to the fact that more cellulose degradation was occurring at a high liquor-to-wood ratio. In general, a high yield with a low Kappa number of pulp product is desirable. If one considers a low Kappa number, the optimum ratio would be 1.9. If one considers the yield as well as the Kappa number, the optimum ratio would be substantially below 1.9. In any event, the most significant point in these experiments is that an effective pulping can be carried out under a liquor-to-wood ratio as low as 1.9. In comparison, other solvent pulping, such as alcohol or ester (especially the volatile pulping reagents) typically requires liquor-to-wood ratios of 5-15. Otherwise, the delignification in the liquid phase becomes extremely inefficient since most of the reagent exists in the gas phase. Nevertheless, very little work beyond a few laboratory tests has been done with organic pulping using less volatile solvents such as MEA. For one reason; they are difficult to recover. In the MEA pulping, the L/S ratio can be reduced to one-fifth to one-tenth that of other organic pulping using volatile reagent. The low liquor-to-wood ratio may play a critical role in reducing the solvent loss in the process. To validate this point the following equations were derived addressing the solvent recovery factor. The following assumptions were made to quantify this concept: 1) Comparisons between high and low liquor were made on the basis of equivalent initial quantities of fresh liquor. 2) Liquor is repeatedly recycled at fixed ratio. 3) The solvent concentration in low liquor is the same as that in high liquor.

Notation

R	: recovery factor in high liquor pulping
r	: the ratio of liquor to wood in high liquor cooking
K	: the ratio of high liquor to low liquor
Q	: the amount of fresh liquor in high liquor cooking
S	: sum of fresh and recycled liquor in repeated cycles of high liquor cooking
h, l	: refers to high liquor pulping and low liquor pulping respectively

The total of liquid throughput including the repeated recycle streams of an infinite geometric series, can be expressed as:

$$S_l = Q_l + R_l Q_l + R_l^2 Q_l + \ldots = \frac{Q_l}{1 - R_l} \tag{2}$$

$$S_h = Q_h + R_h Q_h + R_h^2 Q_h + \ldots = \frac{Q_h}{1 - R_h} \tag{3}$$

From assumption 1:

$$Q_h = Q_l \tag{4}$$

By definition:

$$K = \frac{r_h}{r_l} \tag{5}$$

Assumption 2 leads to:

$$S_h = KS_l \tag{6}$$

Substitution of equation 2, 3 into equation 6 yields

$$\frac{Q_h}{1 - R_h} = K \times \frac{Q_l}{1 - R_l} \tag{7}$$

Substitution of equation 4 into equation 7 yields

$$R_l = 1 - K \times (1 - R_h) \tag{8}$$

Table 2. Reduced Recovery Factors in Low Liquor Pulping that Corresponds to Recovery Factors in High Liquor Pulping

K	R_h	.50	.60	.70	.80	.90	.95	.99
				CRF in LLC[1]				
2	I	0	.20	.40	.60	.80	.90	.98
3	I	+	0	.10	.40	.70	.85	.97
4	I	+	+	+	.20	.60	.80	.96
5	I	+	+	+	0	.50	.75	.95
6	I	+	+	+	+	.40	.70	.94
7	I	+	+	+	+	.30	.50	.93
8	I	+	+	+	+	.20	.60	.92
9	I	+	+	+	+	.10	.55	.91
10	I	+	+	+	+	0	.50	.90

+ no recycle with less initial liquor
[1] corresponding recovery factor in low liquor cooking

Table 2 was constructed from equation 8. Table 2 lists recovery factors in low-liquor pulping corresponding to various recovery factor in high-liquor pulping. It lists the Corresponding Recovery Factor in Low-Liquor Cooking (CRF in LLC) for R_h values ranging from .5 to .99 and K values of 2 to 10. To illustrate the results of the CRF in LLC, three cases (K=2, 5, and 9) are presented in Figure 3. For example, when k=5 and recovery factor= 0.80, the CRF in LLC is zero. This means that the same quantity of pulp is produced in LLC without solvent recovery as in HLC with 80% recovery. When K=10 and recovery factor = 95 % in high-liquor pulping, the CRP in LLC is 50%. In this case the same quantity is produced with 50% recovery as in HLC with 95% recovery. A high amount of liquor also brings about additional costs in digester operation and in equipment. If these costs were taken into account, the corresponding reduced recovery factors in economic terms could be even less than those listed in Table 2.

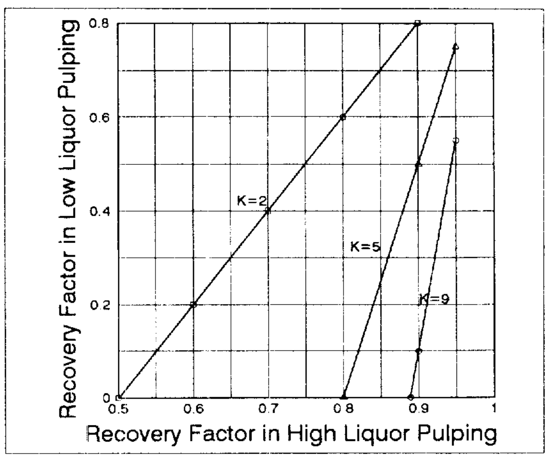

Figure 3. Low Liquor vs. High Liquor (Recovery Factor)

Acknowledgements

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