

# Improvement of Wet-end Performance and Paper Strength with Polyvinylamine

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## ABSTRACT

This study was performed to introduce recently developed polyvinylamine as a wet-end process and paper strength improving aids. As a retention and drainage aids, high cationic charged polyvinylamine was more effective at the BCTMP and ONP stock condition than LBKP stock condition. As a dry tensile strength aid, dual system of polyvinylamine with anionic polyacrylamide was the best at the LBKP or ONP stock conditions. On the other hand, polyvinylamine alone was better than dual system of polyvinylamine with anionic polyacrylamide at the BCTMP condition. As a wet tensile strength aid, polyvinylamine single system and dual system of polyvinylamine with anionic polyacrylamide were good at LBKP, BCTMP and ONP stock conditions. However, poly(aminoamide)-epichlorohydrin resin was good at LBKP and ONP stock conditions but efficiency of poly(aminoamide)-epichlorohydrin resin was remarkably decreased at BCTMP stock condition.

*Keywords : polyvinylamine, retention and drainage aids, dry strength aids, wet strength aid*

## 1. Introduction

The components of the paper are pulp part, mineral part and organic polymer part (1). Because organic polymers among the above components are easy to modify molecular weight, molecular weight distribution, they are applied various papermaking fields as a retention and drainage aids, dry strength aid,

wet strength aid etc (1-3). And recently developed polyvinylamine was expected unique performance compare to traditional polymers like glyoxalated polyacrylamide, poly(aminoamide)-epichlorohydrin resin etc. Because cationicity of polyvinylamine was very higher than others and carbonyl functionality of vinylformamide could generate acetal and hemiacetal bond, it has been reported very good wet strength aid and

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retention aid (4-9). In this study, we studied polyvinylamine according to cationicity and dual system of polyvinylamine with anionic polyacrylamide as a wet end improvement and paper strength aid to compare traditional glyoxalated polyacrylamide and poly-(aminoamide)-epichlorohydrin resin.

## 2. Materials and Methods

### 2.1. Pulps and materials

LBKP, BCTMP and ONP were used as a pulps for the laboratory handsheet making. Table 1 shows analysis of applied polymers. Cationicity of polyvinylamine (PVA) was increased according to the hydrolysis rate. Even though viscosity was decreased by hydrolysis rate, but it was not considered a evidence of decrease of molecular weight but a result from dilution effect by reducing total solid. Viscosity of glyoxalated polyacrylamide (GPAM) was relatively lower than others. Why because too much molecular weighted GPAM tends to form gel by cross-linking effect of glyoxal and polyacrylamide. anionic polyacrylamide (APAM) was selected to simulate dual system of PVA with APAM. Poly-(aminoamide)-epichlorohydrin resin (PAE) also selected for comparison test of wet strength because it is widely used in the paper mills. Fig. 1 shows mechanism of PVA by hydrolysis of poly(N-vinylformamide).

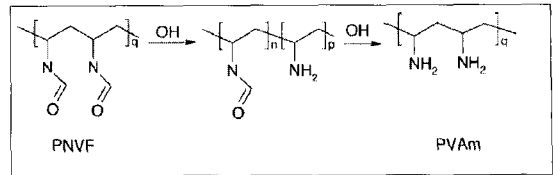


Fig. 1. Chemical reaction formula of polyvinylamine synthesis from poly(N-vinylformamide).

Because it is very difficult to reach hydrolysis rate of 100%, therefore, copolymer form of vinylamine and vinylformamide is prepared in commercial.

### 2.2. Beating

Beatings were performed using laboratory Valley beater by following TAPPI standard T-OM 85. The freeness of stock were LBKP 400 ml CSF, BCTMP 100 ml CSF and ONP 150 ml CSF respectively.

### 2.3 Handsheet making and determination of retention and drainage

Retention, drainage and handsheet making were performed by operation of RDA-HSF Paper machine. The consistency of the stock was 0.18% and the volume of the stock was 1,000 ml. Vacuum condition of the drainage part was 200 mmHg at the main and sub tank. The sequence of chemical contact time of the stock was as followings. At first, stock was introduced to the jar and let it stirred at 1,000 rpm for 15 seconds. and then, cationic polymer

Table 1. Analysis of materials

Analysis Items	PVA-10	PVA-30	PVA-50	PVA-100	G-PAM	A-PAM	PAE
Total solid (%)	24	21	19	15	7.5	15	12.5
Cationicity (meq/g)	1.65	3.8	7.2	11	1.2	-3.8	3.1
Viscosity(cPs)	32,600	12,040	8,350	2,450	18	2,200	45
pH	6.9	7.2	7.1	6.9	3.4	7.2	3.9

was added and let it stirred at 1,000 rpm for 15 seconds. and if needed, anionic polymer was added and let it stirred at 1,000 rpm for 15 seconds. Retention were estimated to measure turbidity of white water using 2020 LaMotte turbidimeter and drainage were compared by the slope of vacuum profile. Finally 60 g/m<sup>2</sup> basis weight handsheets were used to compare strength properties after drying at the 130°C using drum dryer.

## 2.4 Measurement of paper strength

Dry tensile strength and wet tensile strength were measured by following procedures of TAPPI standard T-494 OM01 and TAPPI Standard T-403 OM02. In case of measuring wet tensile strength, water soaking time was 5 minutes.

## 3. Results and Discussion

### 3.1 Retention and drainage

Fig. 2 shows the retention results of the each stock conditions. In case of LBKP stock condition, improvement of retention with PVA was not noticeable, however GPAM and dual system of PVA and APAM resulted weak but linearly improved. It can be considered cationicity of PVA was too high to react properly with LBKP of low anionic charge. On the other hand, in case of BCTMP or ONP stock conditions, improvement of retention according to cationicity of PVA was quite remarkable and dual system of PVA with APAM was favorable however GPAM alone resulted poor retention. Since cationic demands of BCTMP and ONP stocks were much higher than LBKP stock therefore, reaction between PVA and fines induced flocs to improve retention. Low cationicity and low molecular weight of GPAM

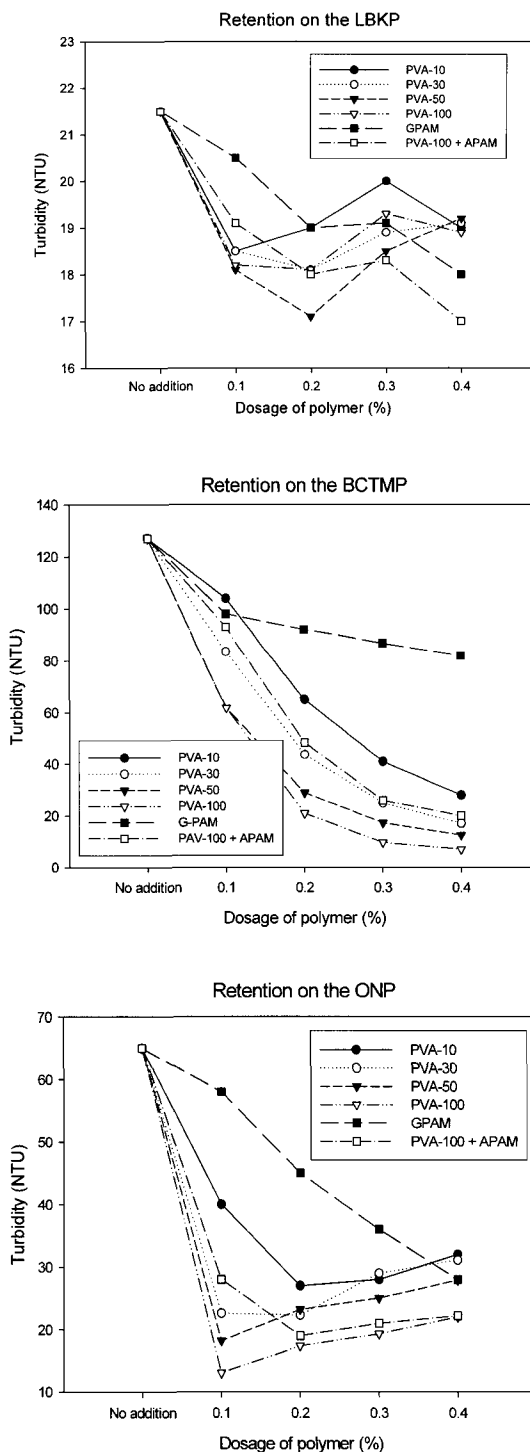
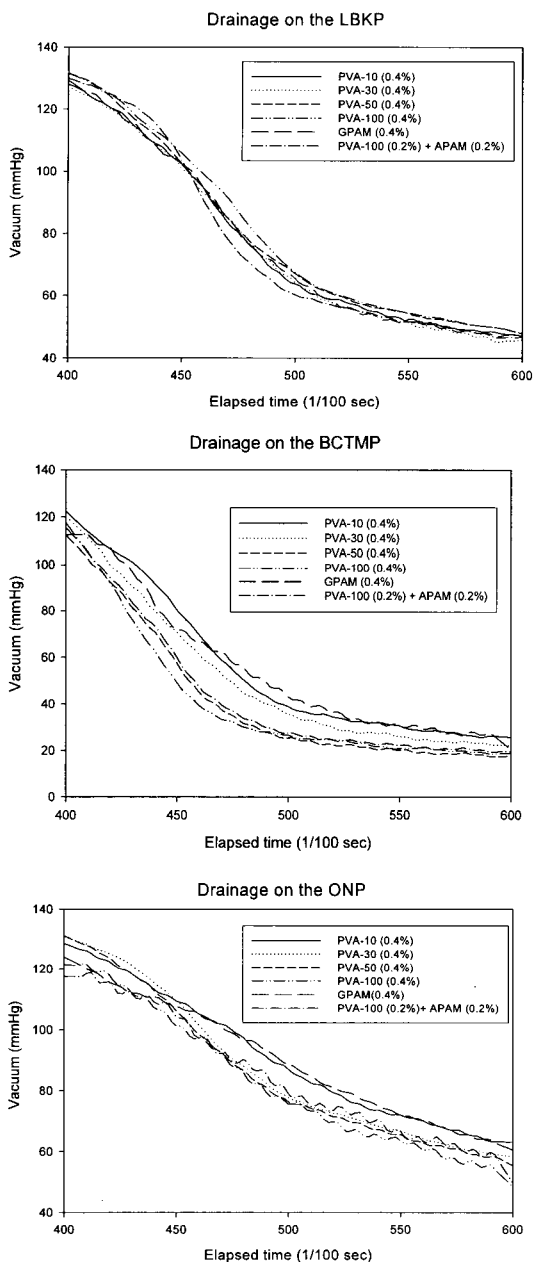


Fig. 2. Retention of polyvinylamine according to ionicity on the LBKP /BCTMP /ONP.

**Table 2. Comparison of cationic demand (filtrate of 250  $\mu\text{m}$  glass filter)**

Pulp (0.18 %)	LBKP	BCTMP	ONP
Cationic demand (0.001N p-DADMAC ml)	0.089	0.371	0.254

**Fig. 3. Drainage of polyvinylamine according to ionicity on the LBKP /BCTMP /ONP.**

resulted poor retention property in the BCTMP and ONP conditions. Table 2 shows cationic demands of each stock conditions. Cationic demand of BCTMP and ONP stocks resulted higher than LBKP.

Fig. 3 shows the drainage results of the each stock conditions. Distinction of efficiency at 0.4% polymer condition resulted more clear than other polymer dosages, therefore 0.4% polymer condition was selected to compare drainage properties. We can see drainage improvement of PVA in the BCTMP and ONP conditions much better than LBKP condition. This result shown considered the similar reasons of retention results.

### 3.2 Paper properties

#### 3.2.1 Dry tensile strength

Fig. 4 shows the dry tensile strength results of the each stock conditions. As increase cationicity of PVA, dry tensile strengths were improved at the all stock conditions of LBKP, BCTMP and ONP. In case of LBKP stock condition, performance of the PVA was lower than G-PAM, however dual system of PVA and APAM was shown much improved performance at the LBKP or ONP stock conditions. This phenomena could be explained that hydrogen bond between amide functionality of PAM and hydroxyl functionality of pulp fibers was very important to improve dry tensile strength. In case of BCTMP and ONP stock conditions, dry tensile strengths were significantly improved by increase cationicity of PVA. Ionic bond between amine and fines as well as reaction of carbonyl

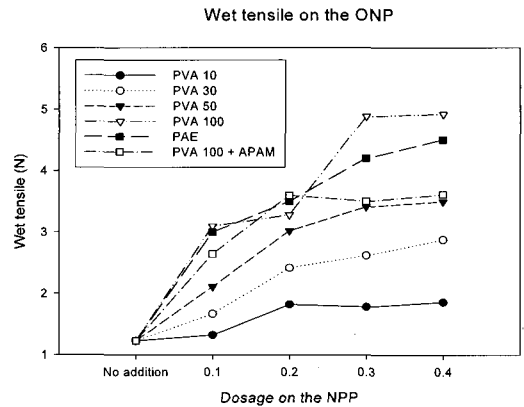
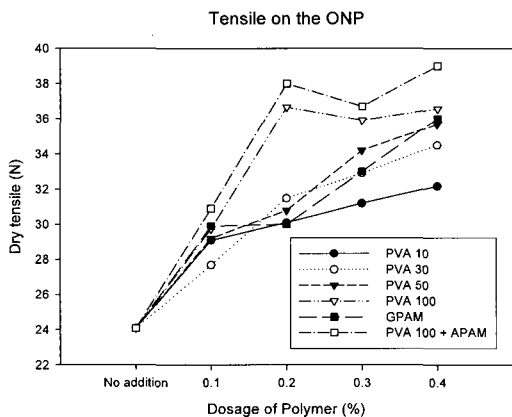
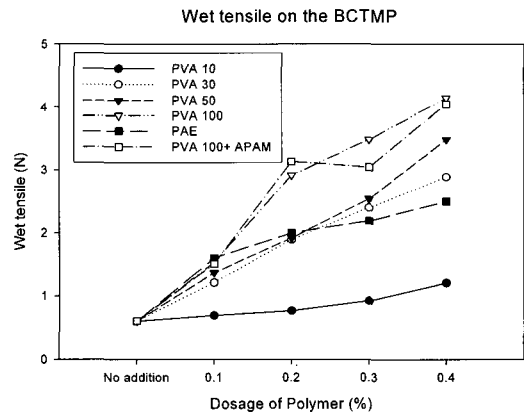
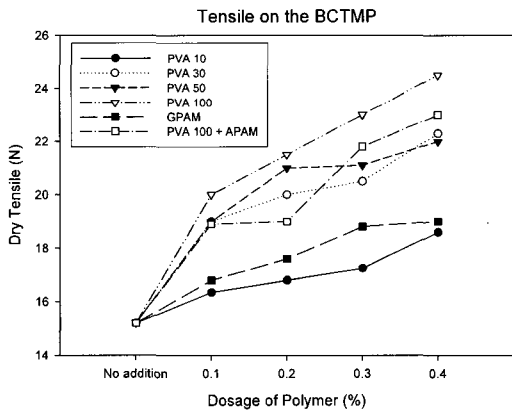
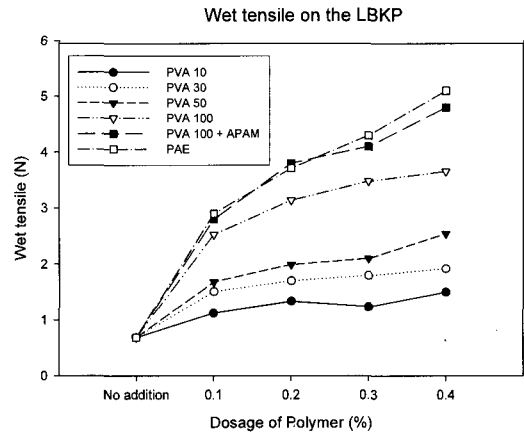
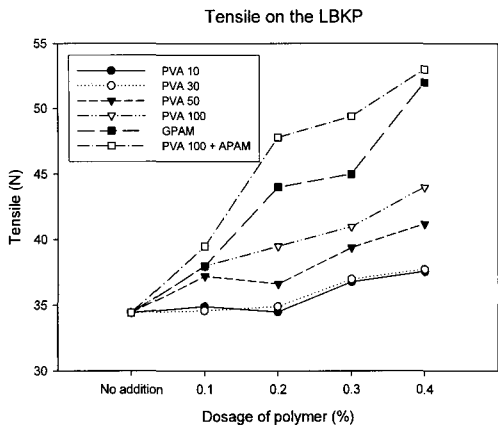


Fig. 4. Dry tensile strength on the LBKP / BCTMP /ONP.

Fig. 5. Wet tensile strength on the LBKP / BCTMP /ONP.

functionality of PVA and hydroxyl functionality of pulp which induce acetal and hemiacetal bond was considered to improve strength properties of LBKP, BCTMP and ONP. Efficiency of GPAM was relatively low with BCTMP and ONP because its low cationicity with low molecular weight easily lose activity in the abundant anionic substances of BCTMP or ONP condition.

### 3.2.2 Wet tensile strength

Fig. 5 are the wet tensile strength results of the each stock conditions. In case of all stock condition, dual system of PVA with APAM or single system of PVA resulted good performance. However, in case of BCTMP stock condition, PVA was much better performance than PAE. It can be explained Azetidinum chloride form of PAE can make acetal bond to increase wet strength but, cationicity of PAE is 3.1 meq/g which is much lower than 11 meq/g of PVA

therefore, activity of PAE was reduced with anionic substances of BCTMP condition. On the other hand, PVA has high cationic charge which is much stable at high anionic substance conditions of BCTMP or ONP stocks as well as carbonyl functionality to induce acetal and hemiacetal bonds with pulp which are effective to improve wet strength.

## 4. Conclusions

1. As a retention and drainage aids, high cationic charged polyvinylamine was more effective at the BCTMP and ONP stock condition than LBKP stock condition. This could be considered reaction of polyvinylamine with anionic substances induced flocs and improved retention and drainage.

2. As a dry tensile strength aid, dual system

of polyvinylamine with anionic polyacrylamide was the best at the LBKP or ONP stock condition. On the other hand polyvinylamine alone was better than dual system of polyvinylamine with anionic polyacrylamide at the BCTMP condition. it was considered hydrogen bond of amide functionality of anionic polyacrylamide with hydroxyl functionality of pulp increase efficiency of polyvinylamine at the LBKP and ONP conditions but activity of anionic polyacrylamide was decreased at the high anionic substance condition like BCTMP condition.

3. As a wet tensile strength aid, polyvinylamine single system and dual system of polyvinylamine with anionic polyacrylamide was good at LBKP, BCTMP and ONP stock conditions. However, poly(aminoamide)-epichlorohydrin resin was good at LBKP and ONP stock conditions but efficiency of poly(aminoamide)-epichlorohydrin resin was remarkably decreased at BCTMP stock condition. this was considered to lose activity of poly(aminoamide)-epichlorohydrin resin of low cationicity in the relatively high amount of anionic substances in the BCTMP.

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