# Application of PEI and PAC as Anionic Trash Catcher to Improve The Paper Properties of Aspen APMP Containing Furnish-a Case Study



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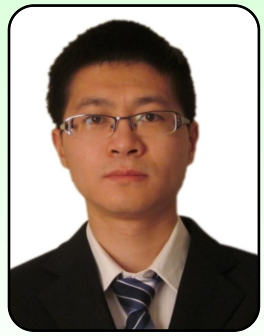
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## ABSTRACT

This research was carried out under the simulation conditions of papermaking in industrial scale. The influences of polyethylenimine (PEI) and polyaluminium chloride (PAC) on wet end system and paper properties were discussed based on circulating white water, neutral sizing, double component retention and drainage aid system, filler loading and so forth. The analysis focused on the impact of anionic trash catcher (ATC) on some key parameters of aspen alkaline peroxide mechanical pulp (APMP), including Zeta potential, cationic demand, furnish drainage, filler retention, and paper properties, including sizing degree, tensile index, tearing index, bursting index, and cohesion. The relationship between ATC and wet end electrochemical environment in furnish, forming process, and paper properties were also discussed. The results show that PEI and PAC are two types of excellent ATC, which are efficient in neutralizing negative charges of anionic trash but partially adsorbed on fibers with negative charges. Relatively, PEI shows relatively better performances than PAC. The introduction of PEI and PAC into the pulp can not only reduce the cationic demand of aspen APMP pulp, but also improve furnish drainage and single-pass retention (SPR) of the filler. Besides, PEI and PAC can improve the sizing results of alkyl ketene dimmer (AKD) significantly as well as enhance the tensile index, bursting index, tearing index, and cohesion of paper. PEI shows better performance than PAC on improvement of sizing degree and cohesion, but no advantage on the strength parameters. The optimum PEI dose ranges from 0.1% to 0.2%.



***Keywords:*** *anionic trash catcher; aspen APMP; paper properties; retention and drainage aid; wet end chemistry*


## Introduction

The concentration of anionic trash from wet end of papermaking machine becomes much higher because of the numerous applications of high yield pulp and secondary fibers as well as the enhancement of white water closure in papermaking machine[1]. The anionic trash is the dissolved colloidal substances that not only consist of added chemicals but also raw material components such as anionic hemicellulose, oxidized lignin, resin, and fatty acids [2,3]. The anionic trash can form polyelectrolyte complexes with cationic papermaking additives, thus resulting in a low efficiency of cationic additives, increased wet end chemical cost, reduced drainage, poor product quality and inconvenient manipulation of papermaking machine [4-7]. The most common way to solve the problem is using various anionic trash catchers with high positive charge density to neutralize the negative charges[8,9]. A lot of researches have been done on the application of ATC in neutral sizing of chemical pulp, waste pulp, and high yield pulp around the world machine[10-12]. However, few researches can be found in literatures about the influences of ATC on wet end electrochemical environment of high yield pulp in complex system and papermaking performance in comprehensive consideration of circulating whitewater, neutral sizing, double component retention and drainage aid system, filler loading and so on. This research focused on the influences of two different types of ATC, which are PEI and PAC, on wet end electrochemical environment and forming process such as Zeta potential, cationic demand, furnish drainage, and filler retention in the complex. Some paper properties, such as sizing degree, tensile index, tearing index, bursting index, and cohesions, were also discussed.


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## Experimental

### Materials and chemicals

Aspen alkaline peroxide mechanical pulp (APMP), needle bleached kraft pulp (NBKP) and white water in wire pit were both provided by a paper mill in China. PEI with the molecular weights of 35,000 g/mol was purchased from Qianglong New Materials of Chemical Engineering Co., Ltd., China. PAC, NaOH, $FeCl_3$, and ammonium thiocyanate were purchased from Beijing Pengcai Fine Chemical Engineering Co., Ltd., China. Cationic polyacrylamide (CPAM) with the molecular weights of 300,000 g/mol was purchased from Nuo'er Chemical Engineering Co., Ltd., China. All the chemicals used were analytical grade. Precipitated calcium carbonate (PCC) and Bentonite were provided kindly by Runlong Chemical Engineering Co., Ltd. of Inner Mongolia, China.

## Methods

### *Zeta potential and cationic demand*

Certain amount of APMP was diluted to 0.5% (furnish consistency) using white water followed by Zeta potential measurement. The furnish was then filtered by 200 mesh filter. 100 mL filtrate was taken and centrifuged at the speed of 2000 r/min for 20 minutes. Supernatant from last step was taken to measure the cationic demand. Another ten parts of APMP were diluted to 0.5% (w/w) as well. Different types and doses of ATC were added into the furnish suspensions. The Zeta potentials were measured after all the furnishes were agitated for 10 minutes. Then, the furnishes were filtered using 200 mesh filters. 100 mL filtrate was taken from each of the pulps from last step, and centrifuged. Supernatant from last step was collected to measure the cationic demand.

### *Drainage of the APMP furnish*

1000 mL furnish with 0.5% pulp consistency was agitated after the addition of ATC. 0.05% CPAM (w/w) was added after 10 seconds agitation. 0.5% anionic bentonite (w/w) was added after another 15 seconds agitation. The furnish freeness was measured after another 20 seconds agitation to characterize furnish drainage.

### *Single-pass retention of the filler*

100 mL furnish suspensions with 0.5% and 15% (w/w) PCC loading was evaporated, dried and burned. The ash content of the resultant solid was measured. Another 10 parts of the same furnish were added into the Dynamic Drainage Jar with different types and amounts of ATC. 0.05% (w/w) CPAM was added after 10 seconds agitation at the speed of 500 r/min. 0.5% (w/w) anionic bentonite was added after another 15 seconds agitation. The exit of the Dynamic Drainage Jar was opened after the following 20 seconds agitation. The 10 parts of the furnishes were collected, dried, and burned separately. The ash contents were measured according to TAPPI T211 om-02. SPR of the filler were calculated following the formula (1).

$$\text{Single - pass retention} = \frac{\text{Ash content in handsheet}}{\text{Ash content in stock}} \times 100\% \qquad (1)$$

### *Papermaking process and handsheet properties test*

The mixed furnish, the ratio of NBKP and APMP was 1/3, was diluted to 0.5%. Other species were added in turn, including ATC, 0.15% (w/w) AKD, 15% PCC, 0.05% CPAM, and 0.5% bentonite. The pH of the mixture was adjusted to 8 by NaOH solution. After 5 minutes agitation, the handsheets with basis weight of 60 $g/m^2$ were made and dried at 105°C for 4 hours. The handsheet properties including sizing degree, tensile index, bursting index, tearing index and cohesion were measured. The papermaking process and handsheet property measurement were all according to the TAPPI relevant standards.

## Measurements/analysis

A SZP06 Zeta Potentiostat and a PCD-03 particle charge analyzer from Mütek of Germany was used respectively to measure Zeta Potential and cationic demand of the furnish. Handsheet forming was carried out using BBS-3 Handsheet Former from Germany HG Company. A CSF-20 Canadian freeness tester from TLS Co., Ltd of Spain, DDJ-2 Dynamic Drainage Jar from PRM Co., Ltd. of US, ZL-300A paper and paperboard tensile testing instrument, **XQ-8575A** tearing instrument, MTA-2000C bursting strength meter, **HH-CB1000** SCOTT cohesion instrument were employed respectively to determine furnish freeness, filler SPR, tensile strength, tearing strength, bursting strength, and cohesion according to the relevant TAPPI standards.

## Results and Discussion

### Effect of ATC type and dose on Zeta potential

The impact PEI and PAC on the Zeta potential of the pulp are shown in Fig.1. It is observed that both PEI and PAC result in the increase of Zeta potentials. It indicates that some of the ATC is consumed in the neutralizing of anionic trash as well as adsorbed on the fiber surfaces with negative charges. The Zeta potential increases more for pulp using PEI than PAC at the same ATC dose because PEI has higher cationic charge density than PAC, which can be more easily

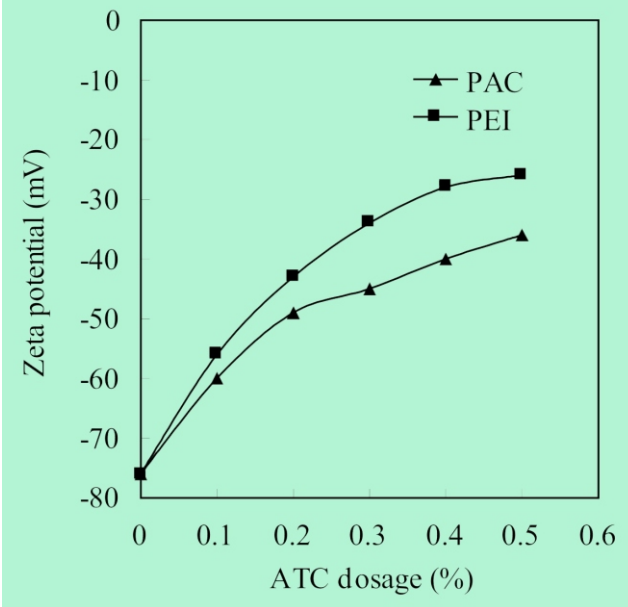


Fig.1 Influence of ATC dose on Zeta potentials of the furnish

adsorbed and neutralized by the negative charges on the cellulose fiber surfaces. The influence of PEI on Zeta potential becomes weaker with the PEI dose ranging from 0 to 0.5%, especially when the dose is higher than 0.4%. The effect of PAC dose on the Zeta potential shows an obvious turning point at the dose of 0.2%. Zeta potential increases with the PAC dose rapidly at the beginning. But the increase slows down and exhibits roughly a linear relationship when the dose is above 0.2%. It is also observed from Fig.1 that there is large rise of Zeta potential of pulps for both ATC with their dose ranging from 0 to 0.5%. But the pulps are still in strong negative charged status, which are far from isoelectric status. This provides better conditions for the interaction between fibers and papermaking additives, such as AKD.

### Effect of ATC type and dose on cationic demand

The best effect of using ATC is to neutralize all the anionic trash in the liquid phase and retain the negative charges of the fibers for the adsorption of electropositive additives on the fibers[9]. The cationic demand reflects the contents of dissolved and colloidal substances (DCS) with negative charges. Therefore, it is necessary to study the effects of the ATC on the cationic demand of the pulp suspension as shown in Fig. 2.

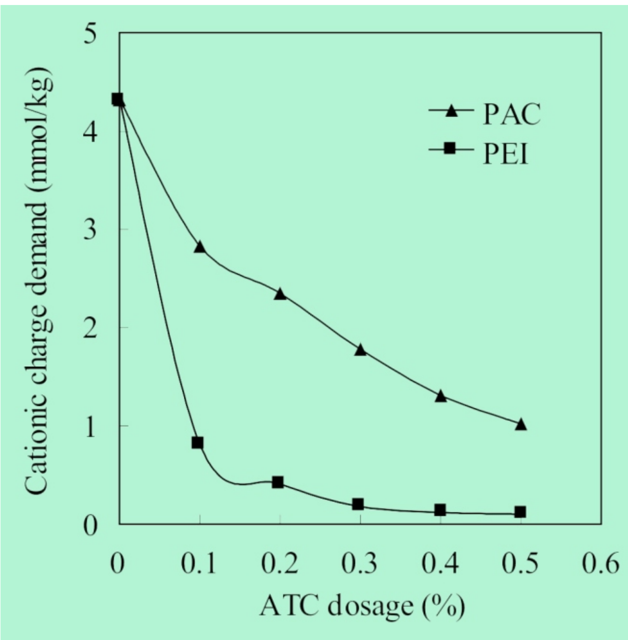


Fig.2 Relationship between ATC dose and cationic demand

It is revealed from Fig. 2 that cationic demand of the pulp suspension is large due to the use of circulating whitewater. With the increasing of doses of the two types of ATC, cationic demand declines sharply. The decreases of cationic demand resulting from PEI are more obvious than from PAC. There is a sharp decline of cationic demand when PEI dose is 0.1%. The decrease becomes less when the PEI dose is above 0.2%, however, Zeta potential of the pulp is still rising. Therefore, most of the PEI are adsorbed on fibers and consumed in the neutralization with negative charges rather than undergo interaction with anionic trash. Therefore, the dose range of PEI is selected from 0.1% to 0.2%, otherwise, too much PEI will result in low efficiency of AKD additives. The cationic demand drops from 4.32mmol/kg to 0.41mmol/kg (90.5% drop) at PEI dose of 0.2%. In comparison, more PAC is needed to reach the same cationic demand values. The cationic demand continue decreasing with the increase PAC dose from 0% to 0.5%. This follows the discipline that the higher the ATC charge density, the stronger is their ability to neutralize anionic substances as well as larger the drop of cationic demand.

### Effect of ATC type and dose on the furnish drainage

There are lots of fines in APMP pulps, which result in bad furnish drainage. It has great impact on the sheet forming process, paper structures and properties. The changes of furnish drainage after the additions of ATC are presented in Fig. 3.

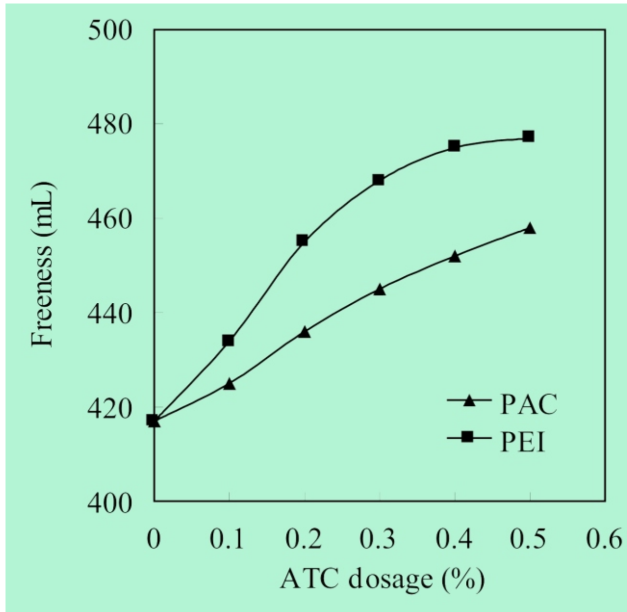


Fig. 3 Relationship between ATC dose and freeness of the furnish

It is observed that both ATCs have drainage aid effect. It is because the ATCs added are polymers with high positive charge density, which can neutralize the anionic trash in the pulp so as to decrease their effects on cationic retention aid of CPAM, more fines and filler particles are connected with fibers by more CPAM molecules via neutralization and adsorption bridging mechanism to form large flocculation. Not only the retentions of fines are enhanced, but also the fiber interspaces are not stuck by the large amount of fines moving with whitewater, which result in a poor furnish drainage. Therefore, the additions of ATC improves the efficiency of CPAM and the furnish drainage. At the same time, both ATCs play roles of drainage aid through bridging mechanism to adsorb and flocculate part of fines in the pulp systems because of the positive charge on them. From the comparison of Fig. 2 and Fig. 3, it is revealed that the decline of cationic demand is very slow when PEI dose is more than 0.2%. It means anionic trash has little negative charges left. Anionic trash has weak effect on CPAM, but the pulp freeness still keeps on increasing. Thus, PEI has better impact on furnish drainage aid on APMP pulp than PAC. The effect of furnish drainage aid is more obvious when PEI dose ranges from 0 to 0.4%, especially when the dose is lower than 0.2%. The effect of furnish drainage aid decreases when PEI dose is more than 0.4%. The effect of furnish drainage aid of PAC continue increasing when the PAC dose changes from 0 to 0.5%.

### Effect of ATC type and dose on SPR of filler

The retention and drainage aid are usually complementary. The effects of PEI and PAC dose on retention aid of pulp additives are shown in Fig. 4. It shows that SPR of the filler increases with the increase in ATC dose. The retention aid effect of PEI is better than PAC. That is because PCC particles have negative charges, which are similar to the fines. The double component aid system of CPAM and bentonite can adsorb and flocculate fines as well as intercept some of PCC particles. The addition of ATC weakens the adverse effects of anionic trash on the retention and drainage aid, which improves the retention effects. PEI, which has higher cationic charge density than PAC, shows better effects. It can also be revealed from Fig. 4 that there are turning points of the retention effects with the rise of doses of the two types of ATC. The turning point is 0.1% for PEI and 0.3% for PAC. When the dose is lower than the value at the turning point, the retention aid effect is more pronounced especially for PEI. The effect drops when the dose is higher than the value at the turning point. There is no big difference on retention aid effect when the doses of the two types of ATC are both 0.3%, and the SPR difference is only 0.47%.

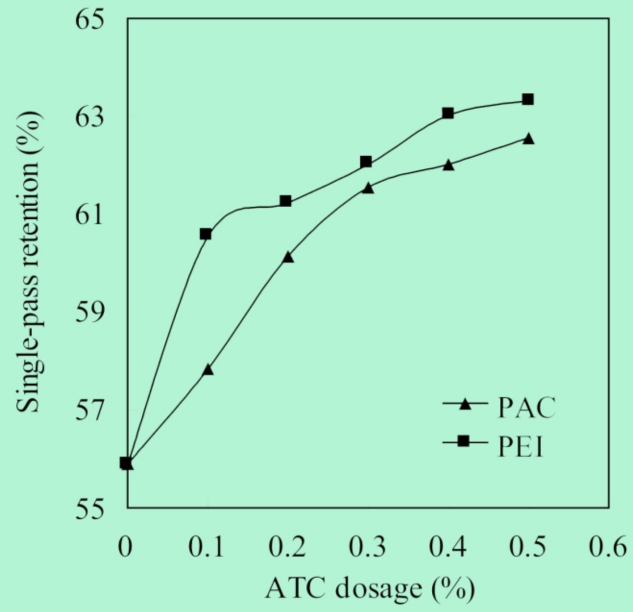


Fig. 4 Relationship between ATC dose and SPR of the filler

### Effect of ATC on sizing degree of paper

High yield pulp (HYP) is usually considered to be more difficult to size than bleached chemical pulp due to its high contents of DCS and fines. Moreover, the higher content of anionic trash in HYP may also affect AKD sizing negatively[13,14]. However, some research results showed that a market HYP had better response to AKD sizing than bleached kraft pulp (BKP) under the same conditions[15]. Even self-sizing of mechanical fibers has also been observed by other researchers[16,17]. Fig. 5 shows the effects of PEI and PAC doses on the sizing degree of paper. The sizing degree of paper is improved with the increase in ATC dose. For PEI, sizing degree is enhanced when the PEI dose is only 0.1%, and then the increase tends to be less. But there is a drop of sizing degree when the PEI dose is more than 0.4%. The possible reason is that appropriate amount of ATC neutralizes the anionic trash in the pulp system, which makes more AKD with positive charges adsorbed on the fiber surfaces with negative charges. But too much ATC results in the adsorption of ATC with positive charges on the fibers, which occupy the positions of AKD. Therefore, considering the effect and the cost, the optimum PEI dose should range from 0.1% to 0.2%, and PAC dose should range from 0% to 0.5% in order to improve the sizing effects.

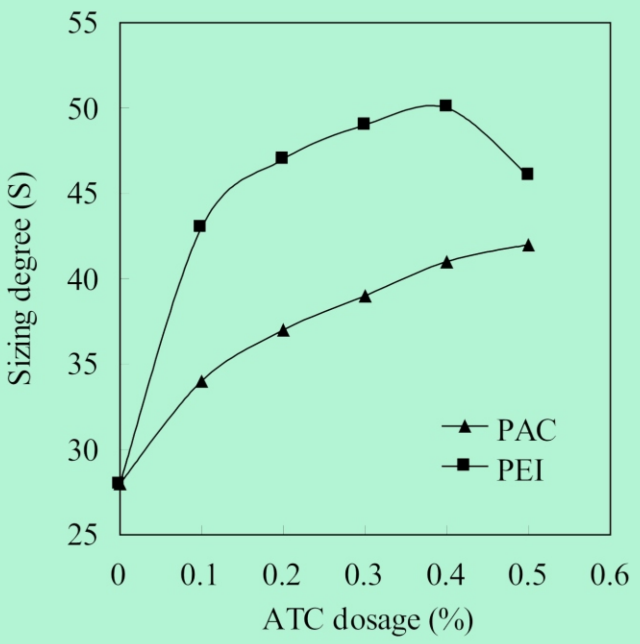


Fig. 5 Relationship between ATC dose and sizing degree of the handsheet

### Effect of ATC on tensile index and tearing index of paper

The addition of ATC results in the increase of tensile index to some extent as shown in Fig. 6. The increase of tensile index by PEI is higher than that by PAC. It is probably because the addition of ATC breaks the anionic trash interference in double component

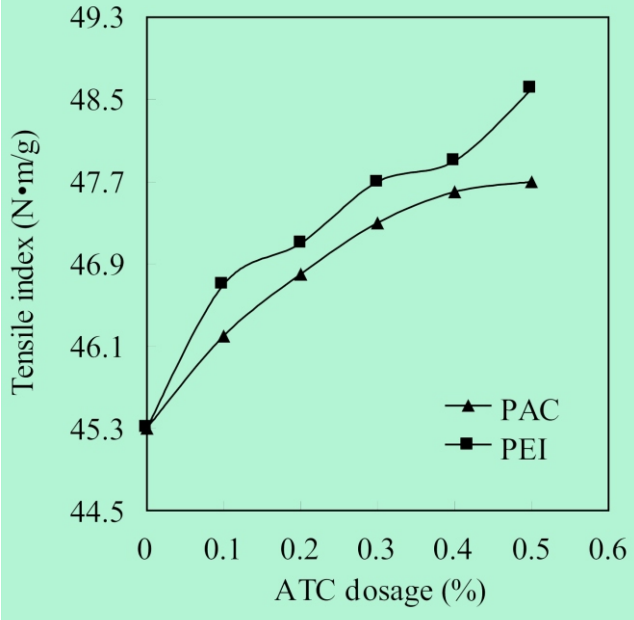


Fig. 6 Relationship between ATC dose and tensile index of the handsheet

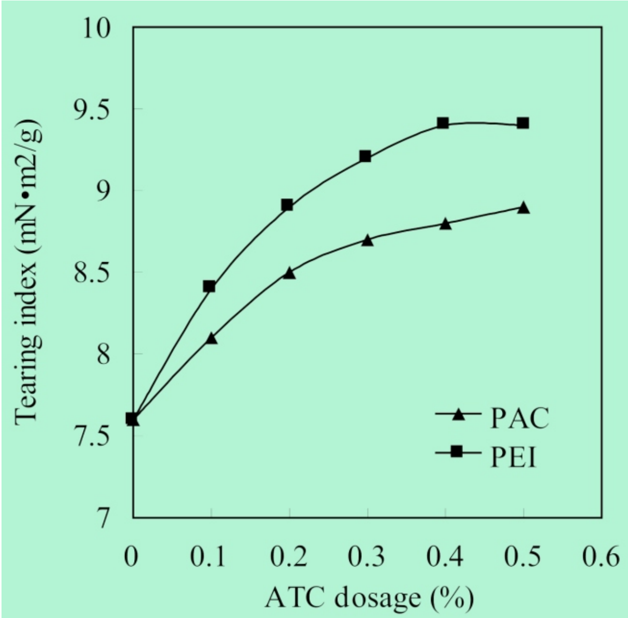


Fig. 7 Relationship between ATC dose and tearing index of the handsheet

retention and drainage aid system of CPAM/bentonite[12]. ATC promotes the retention of fines in APMP. These fines fill some of the interspaces among long fibers to increase the hydrogen bonding between fibers, which enhances the tensile strength of paper. The ATC doses have similar effects on tearing index, which is shown in Fig. 7. The tearing index of paper increases with the increase in ATC dose. When PEI dose is more than 0.4%, the tearing index tend to be stable. The increase of tearing index brought by ATC is benefited from the enhanced binding strength among celluloses fibre. It can be observed that PEI has a better improvement than PAC.

### Influence of ATC on bursting index and cohesion of paper

Fig. 8 shows the effect of ATC dose on **bursting index.** As mentioned before, the addition of ATC leads to the enhancement of binding strength between cellulose fibers. The interfiber binding

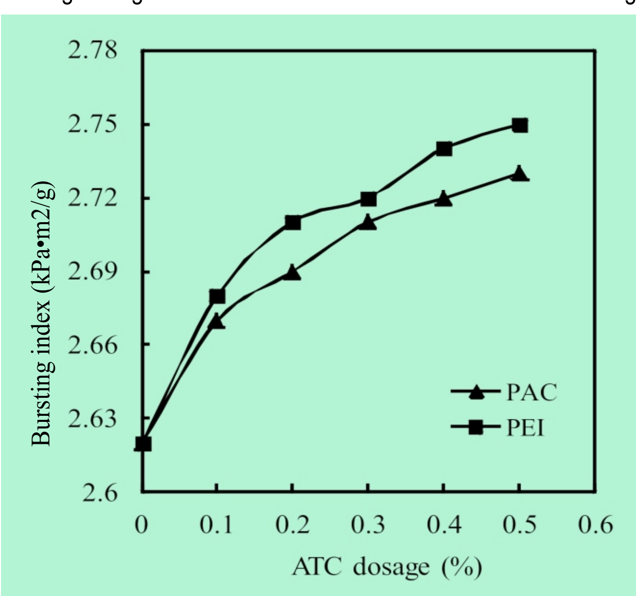


Fig. 8 Relationship between ATC dose and bursting index of the handsheet

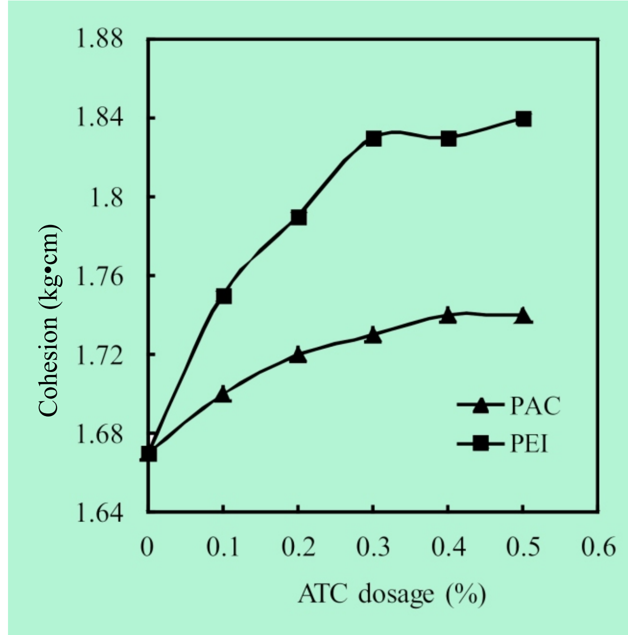


Fig. 9 Relationship between ATC dose and cohesion of the handsheet

strength is the main reason to affect the bursting index of paper. Therefore, bursting index increases with the increase in ATC dose. Cohesion is another important parameter of paper mechanical properties. When paper cohesion is low, some phenomena, including linting, dusting, bubbling, and delamination will occur easily during printing and application of paper. Cohesion has very close relationship with interfiber binding strength. Fig. 9 presents the relationship between ATC doses and cohesion of paper. It is observed that cohesion increases with the ATC dose. PEI shows better performance on impacting cohesion than PAC. Cohesion is more affected by PEI when the dose is lower than 0.3%. The continuous increase of PEI dose has no impact on cohesion.

## Conclusion

PEI and PAC are two different types of the efficient ATC, which can neutralize negative charges of anionic trash in the high yield pulp. But part of the ATC can be adsorbed on the surface of the cellulose fibers with negative charges. PEI has relatively more obvious effect than PAC. The application of PEI and PAC can reduce the cationic demand of APMP pulp suspension, improve the furnish drainage， and enhance the SPR of the filler. PEI and PAC can also improve the sizing effect of AKD as well as increase the tensile index, tearing index, bursting index, tearing index and cohesion of paper. PEI has more pronounced effects on the improvement of cohesion than PAC. The advantages of PEI are not obvious in the other three strength parameters. PEI dose should range from 0.1% to 0.2%.

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