Cationic Polymeric Microparticle Retention Systems and Fines Retention

Derek Maddox
Western Michigan University

Follow this and additional works at: https://scholarworks.wmich.edu/engineer-senior-theses

Part of the Wood Science and Pulp, Paper Technology Commons

Recommended Citation
https://scholarworks.wmich.edu/engineer-senior-theses/298

This Dissertation/Thesis is brought to you for free and open access by the Chemical and Paper Engineering at ScholarWorks at WMU. It has been accepted for inclusion in Paper Engineering Senior Theses by an authorized administrator of ScholarWorks at WMU. For more information, please contact wmu-scholarworks@wmich.edu.
A new cationic polymeric microparticle (CPMP), which is not yet commercialized, has been developed as a retention and flocculation aid. To study the effectiveness of this new cationic polymeric microparticle as a retention aid it was used in conjunction with both a cationic polyacrylamide (CPAM) and an anionic polyacrylamide (APAM). Laboratory evaluation involved using a Britt Dynamic Drainage Jar, two different furnishes and multiple retention system addition levels to test for fines retention. The two systems were then evaluated individually and compared.

It was found that both the CPMP-APAM and CPMP-CPAM systems were beneficial in retaining both fiber and filler fines. It was also seen that the CPMP-APAM system gave better retention results for both furnishes at all addition levels.
# TABLE OF CONTENTS

LIST OF FIGURES ........................................................................................................ iii
LIST OF TABLES ............................................................................................................... iv

## CHAPTER

### I. INTRODUCTION .................................................................................................. 1
   Background and Theoretical ..................................................................................... 2

### II. EXPERIMENTAL PROCEDURE ......................................................................... 5
   Purpose ...................................................................................................................... 5
   Method ...................................................................................................................... 5
   Materials .................................................................................................................. 6

### III. PRESENTATION OF RESULTS ......................................................................... 8
   CPMP-APAM system ............................................................................................... 8
   CPMP-CPAM system .............................................................................................. 12
   Comparison of CPMP-APAM and CPMP-CPAM systems. ............................... 15

### IV. CONCLUSIONS .................................................................................................. 18
   CPMP-APAM system .............................................................................................. 18
   CPMP-CPAM system .............................................................................................. 18
   System Comparison ............................................................................................... 18

### V. RECOMMENDATIONS ......................................................................................... 19

LITERATURE CITED ..................................................................................................... 20
LIST OF FIGURES

1. Filtrate Consistency v. CPMP Addition Level for CPMP-APAM system for furnish 1  8
2. Filtrate Consistency v. CPMP Addition Level for CPMP-APAM system for furnish 2  9
3. First Pass Ash Retention v. CPMP Addition Level for CPMP-APAM system  11
4. Filtrate Consistency v. CPMP Addition Level for CPMP-CPAM system for furnish 1  12
5. Filtrate Consistency v. CPMP Addition Level for CPMP-CPAM system for furnish 2  13
6. First Pass Ash Retention v. CPMP Addition Level for CPMP-CPAM system  14
7. Filtrate Consistency comparison for CPMP-APAM and CPMP-CPAM systems  15
8. First Pass Ash Retention comparison for CPMP-APAM and CPMP-CPAM systems  16
9. Filtrate Consistency comparison for CPMP-APAM and CPMP-CPAM systems  17
TABLE OF CONTENTS

LIST OF FIGURES ........................................................................ iii
LIST OF TABLES ........................................................................ iv

CHAPTER

I. INTRODUCTION ................................................................. 1
   Background and Theoretical .................................................. 2

II. EXPERIMENTAL PROCEDURE ........................................... 5
   Purpose ............................................................................. 5
   Method ............................................................................. 5
   Materials .......................................................................... 6

III. PRESENTATION OF RESULTS .......................................... 8
   CPMP-APAM system ......................................................... 8
   CPMP-CPAM system ........................................................ 12
   Comparison of CPMP-APAM and CPMP-CPAM systems. .... 15

IV. CONCLUSIONS ................................................................. 18
   CPMP-APAM system ......................................................... 18
   CPMP-CPAM system ........................................................ 18
   System Comparison .......................................................... 19

V. RECOMMENDATIONS ........................................................ 20

LITERATURE CITED ............................................................. 21
## LISTS OF TABLES

1. Diagram of Britt Dynamic Drainage Jar ........................................ Appendix I
2. Retention Testing Data for CPMP-APAM system .............................. Appendix II
3. Retention Testing Data for CPMP-CPAM system .............................. Appendix II
CHAPTER 1
INTRODUCTION

There has been a great number of different systems developed to aide in the retention of fibers and fines in the papermaking process. The first pass retention, sometimes referred to as single pass retention, is one of the most significant properties of the paper machine. A low level of single pass retention indicates a high recycle rate of furnish materials with the recirculating white water; it gives rise to non-uniform distribution in the cross-section of the sheet and may contribute to two-sidedness in fourdrinier-made paper. The accumulation of fines and additives in the headbox loop retards drainage, and the fines fraction absorbs a disproportionate amount of certain additives by virtue of its high specific surface area [1].

Throughout this report two microparticle retention systems will be compared and analyzed based on their ability to retain fiber and filler fines. Both systems are similar in that they use a new cationic polymeric microparticle (CPMP). The difference in the two comes in the form of the retention aide polymer employed. The first combines the CPMP with an anionic polyacrylamide, the second a cationic polyacrylamide.
BACKGROUND AND THEORETICAL

The concept of retention aides in the paper industry is an old one. The first basic retention aide was alum, specifically papermakers alum $\text{Al}_2(\text{SO}_4)_3 \cdot 14 \text{H}_2\text{O}$. Alum can be a useful tool in improving retention but it is limited by pH conditions and the low floc strength which has a low shear resistance that is developed through the coagulation mechanism.

Progress and development in the papermaking process and in paper machine technology led to the development of retention aides which could withstand the higher shear forces generated on the new higher speed machines. The first generation of the new retention aides was the single polymer system. These systems generally employ a cationically charged synthetic polymer that will attract the anionic fiber and furnish materials and form flocs through the bridging or patching mechanisms depending on the molecular weight and charge density of the individual polymer. These systems have proven to be simple to use and can be quite effective if used properly.

Further production developments created a need for yet another class of retention aides. Dual polymer or dual component systems were next to be developed. A dual polymer system combines a cationic polymer of low molecular weight and high charge density with an anionic polymer of high molecular weight and low charge density. In this system the cationic polymer is added first to form an effective patch on the surface of the anionic fibers. The anionic polymer is added next to form bridges between the cationic patches on the fibers previously created by the cationic polymer. The flocs developed through this bridging mechanism are known as hard flocs. A hard floc retention system shows good fines retention over a wide range of turbulence and shear for brief periods of
exposure [2]. Another advantage of this system is improved formation and drainage when used and monitored properly. Draw backs to the new dual polymer systems include complications involved in adding the two distinct polymers into the approach system and the associated charge balancing as well as uncontrollable, non-uniform absorption and/or conformation of the polymers to the fiber surface.

Microparticle systems were developed in the early 1980’s as an alternative to the dual polymer systems. Current microparticle systems employ a cationic polymer with an anionic microparticle, typically silica or bentonite. For best results the cationic polymer is added first and allowed to absorb onto the fiber. The anionic microparticle is added late downstream, preferably just before the headbox. The anionic microparticle will be attracted to the fibers which now have the absorbed cationic polymer on their surfaces and flocs will form through the bridging mechanism. The flocs formed this way are highly shear resistant and have been found to reform quickly, smaller than the original flocs. This is where the retention, formation and drainage benefits are realized with the current microparticle systems. Downsides associated with these systems can be pH limitations and typically high cost issues.

This new proposed system utilizes a polystyrene latex based cationic polymeric microparticle (CPMP), which is not yet commercialized, in conjunction with an anionic polyacrylamide (APAM). The supposed mechanism of retention is similar to that of the current microparticle systems. The CPMP will be attracted to the anionic fiber and filler particles in the furnish. The particle will then anchor itself to the fiber and filler particles forming a cationic patch for the APAM to attach to. In contrast to a water-soluble polymer, the microparticle does not get flat on or penetrate into a porous particle because
of its fixed structure. As a result, a more effective patch or bridge may be formed [3].

When the loops and tails of the APAM attach to two or more anchored CPMP particles flocs are formed. In the case of the CPMP-CPAM system it is believed that the pre-absorption of CPMP can prevent CPAM from getting flat on the solid surface, resulting in an extended polymer conformation and high retention efficiency [4].
CHAPTER II

EXPERIMENTAL DESIGN

Purpose

The purpose of this experiment was to determine the fines retention capability of a CPMP-APAM microparticle retention system. A secondary objective was to compare retentions with this CPMP-APAM system to those of a CPMP-CPAM system.

Method

To evaluate these systems retention testing was done using a Britt Dynamic Drainage Jar (BDDJ). A 200 mesh screen was chosen because a fine is generally defined as any material that will pass through a 200 mesh screen. A stirring rate of 1000 RPM was also selected. A schematical example can be found in Appendix I.

The addition level of the CPMP, APAM and CPAM were all varied individually to illustrate the effects dosage on retention.

Testing in the Britt Jar was done as follows. 500 mL of furnish was added to the jar at 0.5% consistency. This was allowed to mix for 30 seconds and the polymer, either APAM or CPAM, was then added. At the 40 second mark the microparticle was added and mixing continued for another 5 seconds and the filtrate was collected. To collect the filtrate the stopcock was opened and a fully developed flow was allowed to ensue. The next 100 mL of filtrate was collected and tested for various retentions. For repeatability all runs were carried out in triplicate.
Filtrate consistencies were measured with a Wattman ashless filter pad in a Buchner funnel. The pads were allowed to dry and were weighed for consistency determination which in turn could be used for retention calculations.

**Materials**

The CPMP for this experiment was provided by Dr. Yulin Deng who is a professor at the Institute of Paper Science and Technology and is also responsible for its development. It is a polystyrene latex based particle prepared using emulsion or microemulsion polymerization. This CPMP was added at levels of 0.5, 1.0, 1.5 and 2.0 lb/T.

The cationic polymer had a molecular weight of 12,000,000 and 20% charge. The anionic polymer had a molecular weight of 15,000,000 and 30% charge. Both polymers were added at levels of 1.0 and 2.0 lb/T.

The cationic polymer was received in a made-down form. The polymer make-down had been performed at a local mill approximately 2 hours before the experiment was conducted. This make-down procedure utilized a high shear gear pump as is standard practice at most paper mills using polymer emulsions. The anionic polymer however was made-down using the Britt Jar at a stirring rate of 3000 RPM for 2 minutes. Both polymers were made-down to a 1.0% consistency.

Two furnishes were used to carry out this experiment. Furnish 1 was a simulated fine paper furnish consisting of 80% bleached hardwood kraft (BHWK) and 20% bleached softwood kraft (BSWK). This furnish was then baseloaded with 15% precipitated calcium carbonate (PCC) added on a mass basis. The fibers were first
beaten in a valley beater until a freeness of approximately 250 CSF was reached. This resulted in a combined fines fraction of 51.6%.

The fines fraction of the pulps were determined by running the Britt Jar at a stirring rate of 1000 RPM and flushing the slurry with fresh water until the filtrate became clear. The filtrate collected was then used to make a filter pad which was weighed. A mass basis determination was then made for the fines percentage.

Furnish 2 was a fiber only furnish consisting of the same 80/20 HW/SW as above taken out of the same beater load and thus having the same freeness of approximately 250 CSF. The fines fraction of this furnish was determined to 44.6%.
CHAPTER III

PRESENTATION OF RESULTS

The results of this experiment will be presented in graphical form. Tables containing the numerical data are presented in Appendix II.

CPMP-APAM SYSTEM

Figures 1 shows the relationship between fines retention and CPMP-APAM addition levels for furnish 1.

Figure 1 shows a trend of decreasing filtrate consistencies as the CPMP addition level is increased for both polymer addition levels. This demonstrates that the CPMP is beneficial in retaining both fiber and filler fines. Increasing the CPMP addition from 0.5
lb/T to 2.0 lb/T yielded a decrease in average filtrate consistency from .036% to .0316% and from .0323% to .0203% for the low and high polymer levels respectively. Along with this trend it is easy to see that the higher polymer level is slightly superior to the lower level. This would lead to the conclusion that the retention mechanism is a function of both components of the system. Three blank runs was made, ones in which there were no retention aide components added, to give a baseline for comparison. The results for this were an average consistency of 0.059%. Comparing this to any of the data points for the CPMP-APAM system it could lead to the conclusion that the CPMP-APAM system is beneficial in retaining both fiber and filler fines.

Figures 2 shows the relationship between fines retention and CPMP-APAM addition levels for furnish 2.

![Graph showing relationship between fines retention and CPMP-APAM addition levels](image)

**FIGURE 2.**
Figure 2 shows a relationship of decreasing filtrate consistencies with increasing CPMP-APAM addition levels. The trend here is slightly less clear. In this case it was the high polymer addition level which started with the highest filtrate consistency, 0.034% at 0.5 lb/T of CPMP, but ended with the lowest consistency, 0.024% at 2.0 lb/T. The trend was as before however, with a steady decrease in filtrate consistency with increasing CPMP level for the high polymer level. The low polymer showed a similar trend but had essentially no change between the 1.0 lb/T and 1.5 lb/T levels. This polymer level yielded a filtrate decrease of 0.032% to 0.026% as the CPMP level increased from 0.5 lb/T to 2.0 lb/T. Again this data would lead to a conclusion that both components of the system are sharing the retention burden.
Figure 3 shows the effectiveness of the CPMP-APAM system for ash retention.

Again the trend here is for increasing ash retention as system components are increased. Also of note is the trend for the higher polymer level outperforming the lower level, keeping consistent with the trends presented earlier. This further substantiates the conclusion that this system is beneficial for retaining filler particles.
CPMP-CPAM SYSTEM

Figure 4 shows the relationship for retention and CPMP-CPAM addition levels for furnish 1.

FIGURE 4.

Figure 4 shows graphically the relationship between filtrate consistency and CPMP and CPAM addition levels for furnish 1. It can be seen here that again the higher polymer dosage provides better retentions than the lower dosage. However there is no clear trend present. It is thought that the two components of the system may actually be interfering and/or repelling each other too much to be effective as possible at these concentrations. The consistencies resulting in using this system are still lower than those for the blank run, in all but one case, but no clear trend in realized.
Figures 5 shows the relationship between retention and CPMP and CPAM addition levels for furnish 2.

The expected trend for decreasing filtrate consistency with increased system additives is again present and readily apparent although they take different shapes. The high polymer level experiences a significant reduction in filtrate consistency from 0.052% at 0.5 lb/T CPMP to 0.047% at 1.0 lb/T CPMP then levels out a bit until reaching 0.0456% at 2.0 lb/T CPMP. The low polymer level has a less significant reduction between the first two CPMP dosages falling from 0.0516% to 0.0493%, experiences a plateau of sorts between 1.0 lb/T and 1.5 lb/T CPMP and falls again between 1.5 lb/T and 2.0 lb/T CPMP from 0.049% to 0.045%.

**FIGURE 5.**
Figure 6 presents the relationship between first pass ash retention and system component addition levels for furnish 1.

It can be clearly seen again that increasing either the CPMP or CPAM led to steadily increasing first pass ash retentions. The low polymer level gave an increase of 42.1% to 45.2% at 0.5 lb/T CPMP and 2.0 lb/T CPMP respectively while the high polymer level gave an increase of 43.6% to 46.2% at 0.5 lb/T CPMP and 2.0 lb/T CPMP respectively.
COMPARISON OF CPMP-APAM & CPMP-CPAM SYSTEMS

Figures 7 - 9 will be presented to show graphically the relationship between the retentions of the two systems. The data points for each polymer and CPMP level is the same as those presented in the discussion of the individual systems.

FIGURE 7.

Figure 7 combines the filtrate consistency data for the APAM-CPMP and CPAM-CPMP systems for furnish 1. It is easy to see that the addition of either retention system is beneficial as all data points, with the exception of one, are below that of the blank run. It is also clear that the higher polymer level performs best for both systems and the CPMP-APAM system performs better than the CPMP-CPAM system at all addition levels.
FIGURE 8.

Figure 8 combines the data for first pass ash retention for the APMP-CPMP and CPAM-CPMP systems furnish 1. A clear trend for increasing ash retention with increased retention system dosage is shown. It is also easy to see that the high polymer level performed best in each system respectively. Again, it would seem the CPMP-APAM system is the superior system when compare to the CPMP-CPAM system at these dosage levels.
Figure 9 combines the data for filtrate consistency for the APAM-CPMP and CPAM-CPMP systems for furnish 2. Here it is very clear that the CPMP-APAM system is providing the better retention capacity at all addition levels. Also, it would seem that once again it is the higher polymer level retaining better than the low level for each system respectively.
CHAPTER IV

CONCLUSIONS

CPMP-APAM SYSTEM

This experiment has shown this system to be beneficial in retaining both fiber and filler fines. All data points observed were significantly below those of the blank runs at all system dosage levels. A clear trend for increased retention with increasing system dosage levels was shown.

CPMP-CPAM SYSTEM

The experiment shows this system is beneficial in retaining fiber and filler fines also. Nearly all the data points observed for this system were again below those of the blank runs. The trends shown for this system were not as clear as for the CPMP-APAM system but the general trend was still for increased retention with increasing system dosage levels was still shown.

SYSTEM COMPARISON

It was shown that the CPMP-APAM system provided better retention characteristics than the CPMP-CPAM system for this experiment.
CHAPTER V

RECOMMENDATIONS

An experiment that used more polymer addition levels, both higher and lower, than those used in this experiment may provide more insight to the feasibility of this new cationic polymeric microparticles application in the paper industry. It may also help to further illustrate the relationship between these system dosages and retention benefits.

Using higher stirring rates with the Britt Jar may be beneficial in demonstrating the effects of higher shear rates for these systems.

Along with different system dosages and shear rates it would be interesting to see how this system responds to different furnishes. Different fiber types and different fillers or combinations of filler types may help decide the fate of this system as a retention aide.

Formation and drainage work is also another avenue to consider. It is well documented how the current silica based programs help improve formation and drainage. No formation or drainage work was done in this experiment due to time and chemical availability.


APPENDIX II
TABLE 1
Data for CPMP-APAM System

<table>
<thead>
<tr>
<th>FURNISH 1</th>
<th>WW CONSISTENCY (%)</th>
<th>RETENTION (%)</th>
<th>ASH RETENTION (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CPMP</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td>1.0 #/T APAM</td>
<td>0.036</td>
<td>0.0356</td>
<td>0.031</td>
</tr>
<tr>
<td>2.0 #/T APAM</td>
<td>0.0323</td>
<td>0.0313</td>
<td>0.028</td>
</tr>
<tr>
<td>BLANK</td>
<td>0.0585</td>
<td>0.0585</td>
<td>0.0585</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FURNISH 2</th>
<th>WW CONSISTENCY (%)</th>
<th>RETENTION (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CPMP</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>1.0 #/T APAM</td>
<td>0.032</td>
<td>0.029</td>
</tr>
<tr>
<td>2.0 #/T APAM</td>
<td>0.034</td>
<td>0.03</td>
</tr>
<tr>
<td>BLANK</td>
<td>0.0515</td>
<td>0.0515</td>
</tr>
</tbody>
</table>
### TABLE 2

Data for CPMP-CPAM System

<table>
<thead>
<tr>
<th></th>
<th>FURNISH 1</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WW CONSISTENCY (%)</td>
<td>CPMP</td>
<td>0.5</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>CPAM</td>
<td>0.06</td>
<td>0.051</td>
<td>0.054</td>
<td>0.047</td>
</tr>
<tr>
<td></td>
<td>1.0 #/T CPAM</td>
<td>0.0477</td>
<td>0.0417</td>
<td>0.0437</td>
<td>0.044</td>
</tr>
<tr>
<td></td>
<td>2.0 #/T CPAM</td>
<td>0.0585</td>
<td>0.0585</td>
<td>0.0585</td>
<td>0.0585</td>
</tr>
<tr>
<td></td>
<td>BLANK</td>
<td>0.0585</td>
<td>0.0585</td>
<td>0.0585</td>
<td>0.0585</td>
</tr>
<tr>
<td></td>
<td>RETENTION (%)</td>
<td>CPMP</td>
<td>0.5</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>CPAM</td>
<td>76.74</td>
<td>80.23</td>
<td>79.06</td>
<td>81.78</td>
</tr>
<tr>
<td></td>
<td>1.0 #/T CPAM</td>
<td>81.51</td>
<td>83.87</td>
<td>83.06</td>
<td>82.95</td>
</tr>
<tr>
<td></td>
<td>2.0 #/T CPAM</td>
<td>77.33</td>
<td>77.33</td>
<td>77.33</td>
<td>77.33</td>
</tr>
<tr>
<td></td>
<td>BLANK</td>
<td>77.33</td>
<td>77.33</td>
<td>77.33</td>
<td>77.33</td>
</tr>
<tr>
<td></td>
<td>ASH RETENTION (%)</td>
<td>CPMP</td>
<td>0.5</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>CPAM</td>
<td>42.1</td>
<td>42.7</td>
<td>44.4</td>
<td>45.2</td>
</tr>
<tr>
<td></td>
<td>1.0 #/T CPAM</td>
<td>43.6</td>
<td>44.7</td>
<td>45</td>
<td>46.2</td>
</tr>
<tr>
<td></td>
<td>2.0 #/T CPAM</td>
<td>76.91</td>
<td>76.91</td>
<td>76.91</td>
<td>76.91</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>FURNISH 2</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WW CONSISTENCY (%)</td>
<td>CPMP</td>
<td>0.5</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>CPAM</td>
<td>0.0516</td>
<td>0.0493</td>
<td>0.049</td>
<td>0.045</td>
</tr>
<tr>
<td></td>
<td>1.0 #/T CPAM</td>
<td>0.0523</td>
<td>0.047</td>
<td>0.046</td>
<td>0.0456</td>
</tr>
<tr>
<td></td>
<td>2.0 #/T CPAM</td>
<td>0.0515</td>
<td>0.0515</td>
<td>0.0515</td>
<td>0.0515</td>
</tr>
<tr>
<td></td>
<td>BLANK</td>
<td>0.0515</td>
<td>0.0515</td>
<td>0.0515</td>
<td>0.0515</td>
</tr>
<tr>
<td></td>
<td>RETENTION (%)</td>
<td>CPMP</td>
<td>0.5</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>CPAM</td>
<td>80</td>
<td>80.89</td>
<td>81.01</td>
<td>82.56</td>
</tr>
<tr>
<td></td>
<td>1.0 #/T CPAM</td>
<td>79.73</td>
<td>81.78</td>
<td>82.17</td>
<td>82.33</td>
</tr>
<tr>
<td></td>
<td>2.0 #/T CPAM</td>
<td>76.91</td>
<td>76.91</td>
<td>76.91</td>
<td>76.91</td>
</tr>
</tbody>
</table>