Effects of tissue additives on copy paper forming and properties

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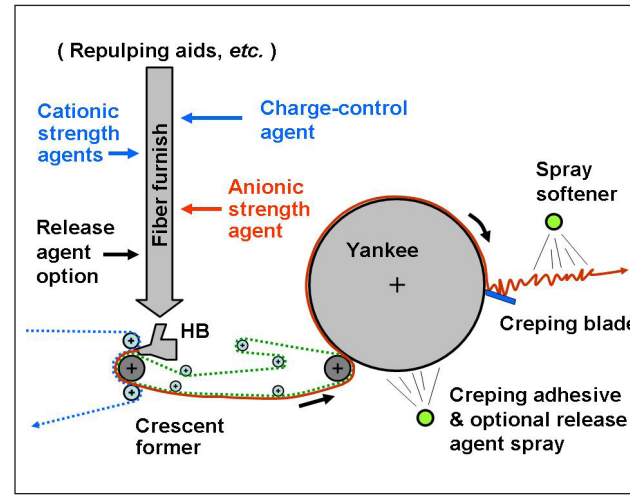
ABSTRACT: Laboratory tests were conducted in an effort to determine the effects on paper machine process attributes and the properties of paper made from recycled copy paper furnish upon the addition of chemical agents that are commonly used in the production of hygiene tissue products. Due to continuing growth in tissue and towel grades of paper, such agents are experiencing greater usage.

Charge titration test results revealed that certain dry strength agents associated with tissue manufacturing have the potential to shift the balance of charge in papermaking furnish to less negative or even positive values. Creping adhesive was found to contribute to fine particle retention, especially when present at relatively high levels. Release aid and a polyacrylate dispersant had the opposite effect. Low addition levels of both a creping adhesive and a debonding agent surprisingly increased a wide range of strength attributes of paper handsheets in comparison to sheets prepared from unaltered recycled copy paper furnish. The debonding agent decreased paper strength at higher levels of addition. Such effects appear to depend not only on the expected effects of agents themselves, but also on how they affect the charge balance of the wet-end system.

Application: Papermaking process engineers can face a variety of challenges, including unexpected interactions between different chemical additives to the process. Expansion of tissue and towel production to mill sites not previously dealing with such products brings the possibility of cross-contamination with production of other paper grades. Partial sharing of process water systems, for instance, can affect both the papermaking process and the attributes of the paper product.

Tissue and towel paper grades have grown steadily in recent years with continuing development of related technology [1]. Paper companies sometimes have the option of installing new tissue or towel paper machines within existing pulp and paper facilities. The present work considers a hypothetical situation in which, due to inadvertent sharing of broke or process water, some of the chemical additives from a tissue paper machine get into the process of a second paper machine that may be making a different product. Regardless of the type of paper being produced, key concerns of paper machine operators are that the operating conditions remain steady and that product properties do not vary over time. Stated another way, the specifications need to be met, regardless of what else may be happening at a mill site.

Figure 1 illustrates categories of chemical additives that might be employed in a typical operation where the product is a tissue paper grade. Typical addition points are shown in a very simple manner, using a downward gray arrow to denote the processing steps leading to the tissue forming machine. The first additives worth mentioning are the "repulping aids," which might include surfactants to help in wetting sheets of dry-lap pulp or recovered used paper. A key factor illustrated in the diagram is that some of the common additives used in tissue production have different signs of ionic charge. Because the cellulosic fibers used by papermakers typically start out with a negative surface charge, mainly due to their hemicellulose content,



1. Simplified representation of a hypothetical tissue paper production system, with indications of common chemical additives and their possible points of addition.

it makes sense that many of the tissue additives added in the wet end have a positive (or cationic) charge. Blue text is used in the figure to denote such cationic additives. This would include not only some charge-control agents (various polyamines or alum-related products), but also various strength agents, such as glyoxylated polyacrylamide (gPAM) copolymers [2-6]. There may be a need for debonding agents (regarded as a kind of cationic surfactant) when manufacturing tissue paper products from recovered kraft

fibers that have already been refined [7]. The opposite charge of these additives relative to the fiber surfaces helps them to be retained efficiently when added to the wet end of a tissue forming machine. Surfactants of various charges may also be used to enhance the rate of water uptake into tissue and towel products [8]. Some strength agents may have an anionic (or negative) charge, as shown in the figure. These utilize the "anchoring points" provided by the previously added cationic agents, now on the fiber surfaces, to be retained efficiently.

Another feature illustrated in Fig. 1 is that tissue producers, when utilizing Yankee dryers and creping operations, can rely on various combinations of release agents and adhesives by which to "tune" the behavior of the sheet at the creping blade [9]. The Yankee dryer consists of a very large steam-heated cylinder. Additives categorized as "release agents," which often have a low surface energy, help ease the release of the paper during creping. Like wax, they are hydrophobic. By contrast, the "adhesive" generally is water-loving, such as a curable adhesive agent. Examples of creping adhesive formulations were studied by Rezaei-Arjomand et al. [10]. The formulations were composed of different amounts of polyamidoamine-epichlorohydrin (PAAE) wet-strength resin, polyvinyl alcohol (as a modifier), and cationic fatty acids and ethylene glycol as release agents. The relative amount of PAAE was found to be critical to the performance of the system. Cationic polyamines have also been used as Yankee adhesives [11]. In addition, it is known that a film of hemicellulose from the pulp can form on the Yankee dryer surface and contribute to adhesion of the sheet [12]. By adjusting the ratios of the different additives, the manufacturer has ways to achieve optimized results.

Variable levels of chemical additives, especially if they are unplanned and not even utilized in a specific papermaking operation, have the potential to impact the process and product in various ways. For example, an excess of certain cationic agents (such as a gPAM product) might cause an unwanted change or reversal of charge in the system. This could result in a change (or instability) in the rate of dewatering. As a worst-case scenario, such instabilities can lead to web breaks. The present work considered such potential impacts by running laboratory experiments to predict effects of various tissue additives not only on drainage, but also on retention of fines and the extent of fiber flocculation.

Rather than being focused on a specific concept, the present work can be described as an exploratory study. In other words, the experimental findings take the lead, and tentative explanations may need further study in follow-up work. In addition, the following hypotheses will be considered in the interpretation of the results, especially when considering the possibility of interactions between different substances:

- Substances having a surface-active nature may have significant effects on sheet formation and drainage due to changes in water surface tension or dispersing effects.
- Substances having an ionic charge may affect retention, drainage, and details of paper structure, depending on how they affect that balance of charges in the system.
- Substances having a hydrophobic nature may tend to interfere with hydrogen bonding between fibers.
- Cationic polymers, even if they are known to be strength agents, may contribute to fiber flocculation, which can lead to decreased uniformity and reduced strength.

The chemical additives featured in the present work include most of those depicted in Fig. 1, with a few additional items. For instance, dispersants comprised of relatively low-mass polyacrylate are widely used in industry. Due to the highly negative ionic charge of such dispersants, it is of concern to find out how they might affect operations while making a printing grade product. In addition, carboxymethylated starch (CMS) was considered. It can be added in sequence after a cationic strength agent, as shown in Fig. 1. Such combinations of cationic and anionic strength agents have shown potential to create very strong interfiber bonding in paper [13], but they also have the potential to create runnability issues [14]. As a way to keep the base furnish properties the same throughout a wide range of experimentation, all of the work to be described involved usage of repulped copy paper having 100% recovered fiber content.

EXPERIMENTAL

Chemicals and materials

Chemical additives employed in the present work are listed in **Table I**, together with a brief description of their intended function and the names of their suppliers. Most of the chemicals were diluted to 1% active solids before use in the experiments, except for the cationic polyacrylamide (cPAM) retention aid, which was prepared at 0.1% active solids as a means of achieving better mixing with the stock. For purposes of calculations, the three dry products (Prosoft TQ1003, Prosoft TQ250, and Aquasol 220 UL) were regarded as having 100% solids content.

Pulp preparation

The fibers used in the present work, along with calcium carbonate ($CaCO_3$) filler and a baseline of typical chemical additives, were obtained by repulping Boise Aspen recycled multi-use paper (Boise Paper; Boise, ID, USA). The resulting furnish was prepared to 0.5% consistency. By taking this approach, it was possible to maintain essentially the same level of refining and other starting properties over the course of several months of experimental work. The initial content of $CaCO_3$ filler in the paper, before repulping, was

Brand name	Description
Crepetrol CS1240	Yankee coating adhesive; polymer blend with both thermosetting and non-thermosetting characteristics, Solenis (Wilmington, DE, USA)
Rezosol CS3280	Yankee coating release aid; hybrid release and modifier, Solenis
Prosoft TQ1003	Wet-end debonder, Solenis
Prosoft TQ250	Improvement of surface softness, Solenis
Hercobond 1315	Glyoxylated polyacrylamide (PAM) temporary wet strength resin, Solenis (gPAM2)
Hercobond 1307	Glyoxylated PAM temporary wet strength resin, Solenis (gPAM1)
Hercobond 6350	Polyvinylamine dry strength technology, Solenis (PVAm)
Hercobond 3500	Amphoteric (net cationic) dry strength additive, Solenis
Aquasol 220 UL	Carboxymethyl starch (CMS), anionic strength agent, Aquasol (North Tonawanda, NY, USA)
Polyoxyethylenelaurate	Nonionic surfactant, as might be used for repulping
Sokalan PA 40	Dispersant: Sodium polyacrylate, BASF (Ludwigshafen, Germany)
Fennosil 2180	Colloidal silica (dewatering additive adjunct), Kemira (Helsinki)
Sodium hydroxide	Often employed as a repulping aid

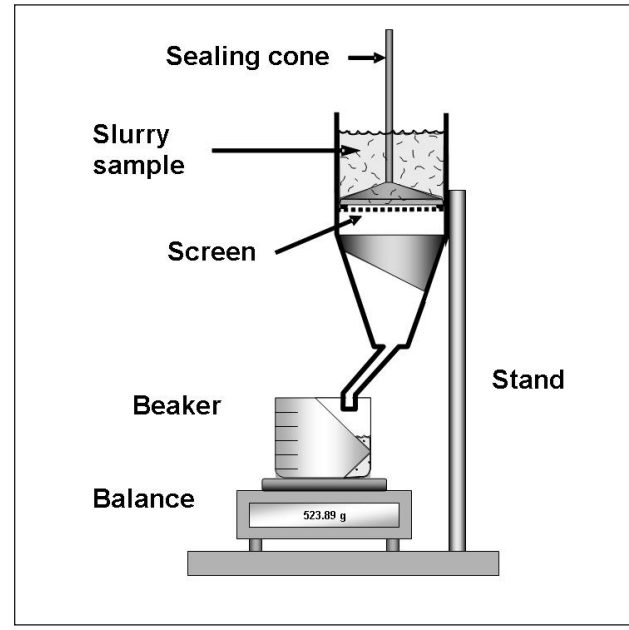
I. Chemical additives.

determined using TAPPI Standard Test Method T 413 "Ash in wood, pulp, paper and paperboard: combustion at 900°C."

The pulp suspension was dosed with sodium sulfate solution until it reached 1.00 mS/cm of electrical conductivity (measured at about 23°C) to simulate typical salt buildup under some paper mill conditions. Past preliminary work in the authors' lab has shown that tests of drainage or retention in the absence of salt show unrealistically high sensitivity to the precise balancing of charges, as well as a tendency to exaggerate some effects of charged additives. The presence of a moderate level of sodium sulfate, which is commonly present in paper machine systems, decreases the thickness of the "double layer" of counter ions at the charged surface and thereby moderates charge interactions, leading to more realistic results.

Dewatering tests

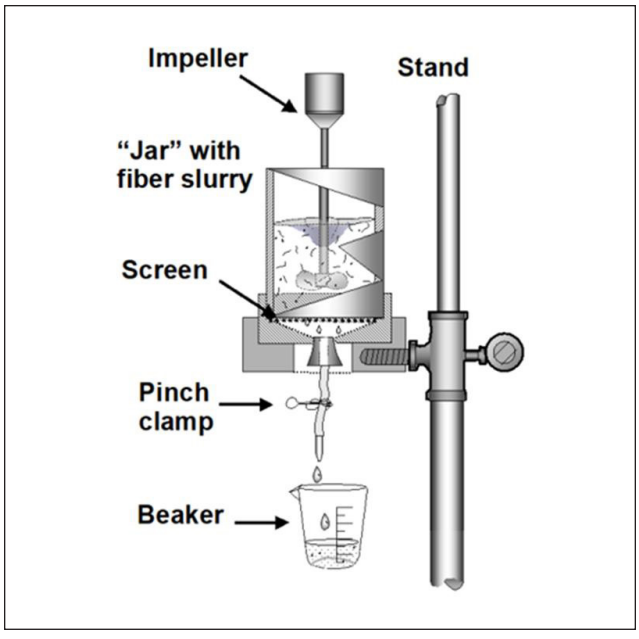
A modified Schopper-Riegler test was used to measure the gravity-induced dewatering rates of pulp slurries under various conditions. **Figure 2** shows a schematic representation of the apparatus used. A 100-mesh screen was used to filter fibers. The mass of fluid that had left the device was measured at 5, 10, 20, 40, and 60 s to observe how the dewatering rate changed over time. As in the case of Canadian Standard Freeness tests, the results are expected to be sensitive to the level of cellulosic fines in the suspension. However, due to gentle hydrodynamic shear conditions during the drainage tests, they are not expected to show high correlation with dewatering rates on specific commercial paper machines.



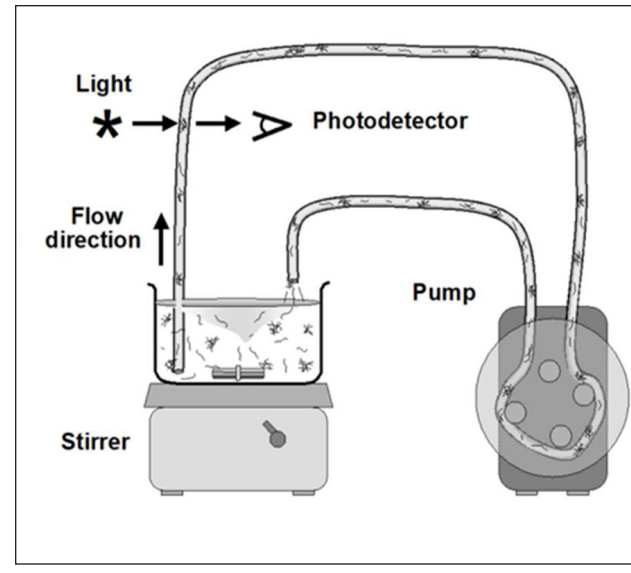
2. Schematic diagram of modified Schopper-Riegler apparatus for determining dewatering as a function of time.

Retention tests

Retention was measured using a Britt dynamic drainage/retention jar [15] fitted with a 200-mesh stainless steel screen, which is the same as used when forming TAPPI handsheets (TAPPI T 205 "Forming handsheets for physical tests of pulp"). **Figure 3** shows the main features of the device. The slurry was mixed continuously, usually at 600 rpm. To sample the turbidity of the filtrate, the clamp was removed temporarily. The first 10–20 mL of filtrate were



3. Main features of the dynamic drainage/retention jar.



4. Setup of the photometric dispersion analyzer system for evaluation of fiber flocculation effects.

dumped back into the Britt jar as the stirring continued. A second sample was then collected. Due to the high amount of $CaCO_3$ in the system, giving a very high turbidity in the absence of chemical additives, the filtrate was diluted with nine times its mass of water. Turbidity measurements were obtained, with tenfold replication [16]. The system was assumed, as a first approximation, to follow the Beer-Lambert law, such that turbidity is proportional to the solids present in the suspension [17]. The mean result was multiplied by ten to account for the ten-fold dilution mentioned earlier.

Flocculation tests

The tendency of different chemical conditions to change the extent of fiber flocculation was evaluated by means of a photometric dispersion analyzer (PDA, low gain version) from Rank Brothers (Newbury, England). The experimental setup is illustrated in **Fig. 4**. First, 500 mL of stirred stock suspension was pumped through a 6-mm inner diameter tube at a rate of 50 mL/min. Both gain constants were set to 1.00. The "RMS" (root-mean-squared components of fluctuations in transmitted light through the flow tube) button and the "Filter" button were selected. Values (with no units) were recorded between about 10 and 120 s after each chemical addition. Though the output from the PDA device is known to increase with increasing visible flocculation, no theory has been developed to connect those results to changes in either the size or the density of fiber flocs.

Streaming potential tests

The streaming potential was determined by measuring the change in electrical potential (mV) vs. the change in applied pressure in the device described by Garland et al. [18]. A vacuum was applied through a 100-mesh screen to separate filtrate from stirred stock. Tests were performed with four replicates at each condition. The zeta potential was found by comparing the voltage vs. the change in applied pressure and using the Helmholtz-Smoluchowski equation [19-21], as follows:

$$\zeta = 4\pi \, \Delta E \, \eta\lambda \, / \, (\Delta P \, \varepsilon)$$

where ΔE is the measured difference in voltage between the probes, η is the viscosity, λ is the electrical conductivity, ΔP is the applied vacuum, and ε is the dielectric constant. For convenience, the following form of the equation, with temperature corrections for viscosity of water and electrical conductivity (relative to 25°C calibration) was used, where θ is the temperature (°C):

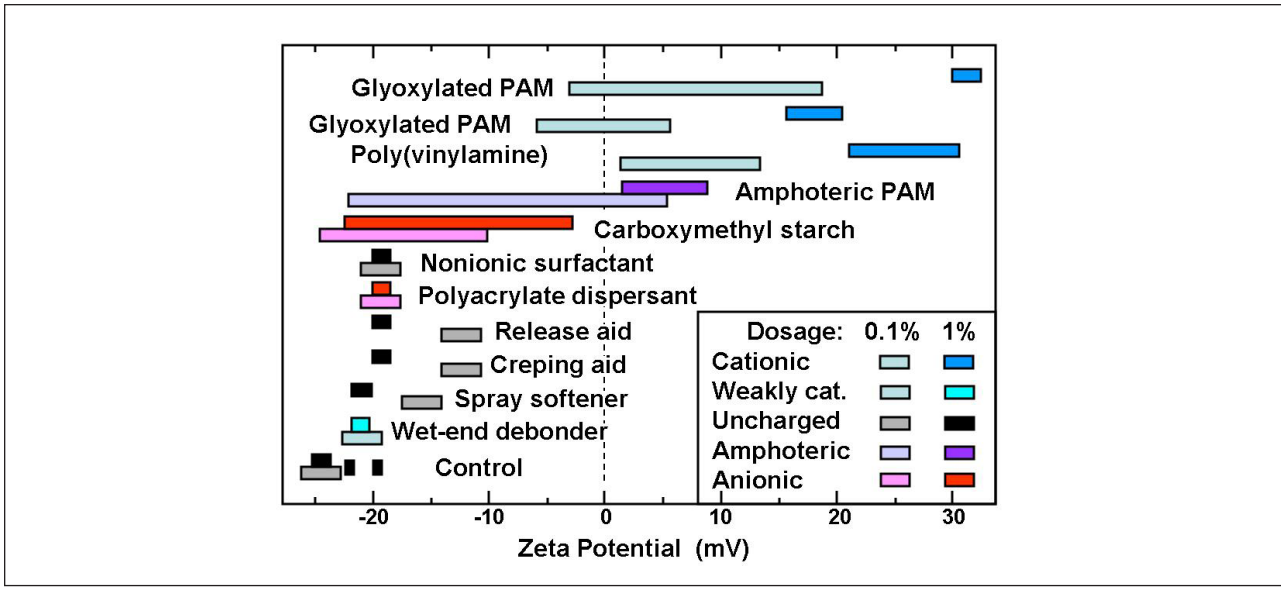
$$\zeta \text{ (mV)} = 12.27 \, \Delta E \text{ (mV)} * [\lambda \text{ (µS/cm)} \, / \, \Delta P \text{ (mm Hg)}] * [1+(25-\theta)/44.74)]/ \, [1+(25-\theta)/223.7)]$$

Charge demand titrations

The charge demand values of various solutions and filtrate specimens were determined by titrations using a streaming current detector to sense the endpoint condition (CAS touch! distributed by emtec Electronic of Leipzig, Germany). The titrants were 0.001 N solutions of poly (diallyldimethylammonium chloride) and poly(vinyl sulfate).

Paper handsheet preparation and testing

Paper specimens for testing were prepared according to TAPPI T 205. Chemical additives were added to the 0.5% consistency default stock described earlier, using an impeller stirrer for mixing and agitation (stirring rate ~400 rpm). Paper tensile strength properties were evaluated using an L&W tensile tester (Lorentzen & Wettre; Kista, Sweden) de-



5. Zeta potential of recycled copy paper furnish after treatment at two dosages with tissue-related substances (in tap water).

vice according to TAPPI T 494 "Tensile properties of paper and paperboard (using constant rate of elongation apparatus)" and T 220 "Physical testing of pulp handsheets." A manual Gurley densometer was used to measure the air permeability of the handsheets following TAPPI T 460 "Air resistance of paper (Gurley method)."

RESULTS

Filler content

Duplicate tests of the 900°C ash content of the default copy paper (used as the source of furnish solids) indicated the presence of 12.7% of calcium oxide (CaO), under the assumption that all ash had come from $CaCO_3$ that had been fully converted to CaO burnt lime during the standard incineration. Based on an ignition factor of 0.56 (the mass of CaO over $CaCO_3$) and a measured 6.0% moisture content of the paper under storage conditions, this implies a filler content of 22.7%.

Zeta potentials

As shown in **Fig. 5**, there were several different sets of zeta potential results obtained for the control sample of stock. This is due to the testing variation associated with different lab teams. This variation contributed to some of the broad ranges seen while testing each individual additive.

In general, following the addition of nonionic surfactant, cationic softening agent, and highly anionic dispersant, the zeta potential was not significantly affected. The lack of significant results from the weakly cationic softening agent may be due to its highly hydrophobic and insoluble nature, which would prevent it from interacting strongly with charged materials dissolved in aqueous solutions. The highly anionic strength agent and low-mass polyacrylate dispersant, which both have the same charge as fibers, may not have adsorbed onto the fibers, which would explain the lack of effect on the zeta potential.

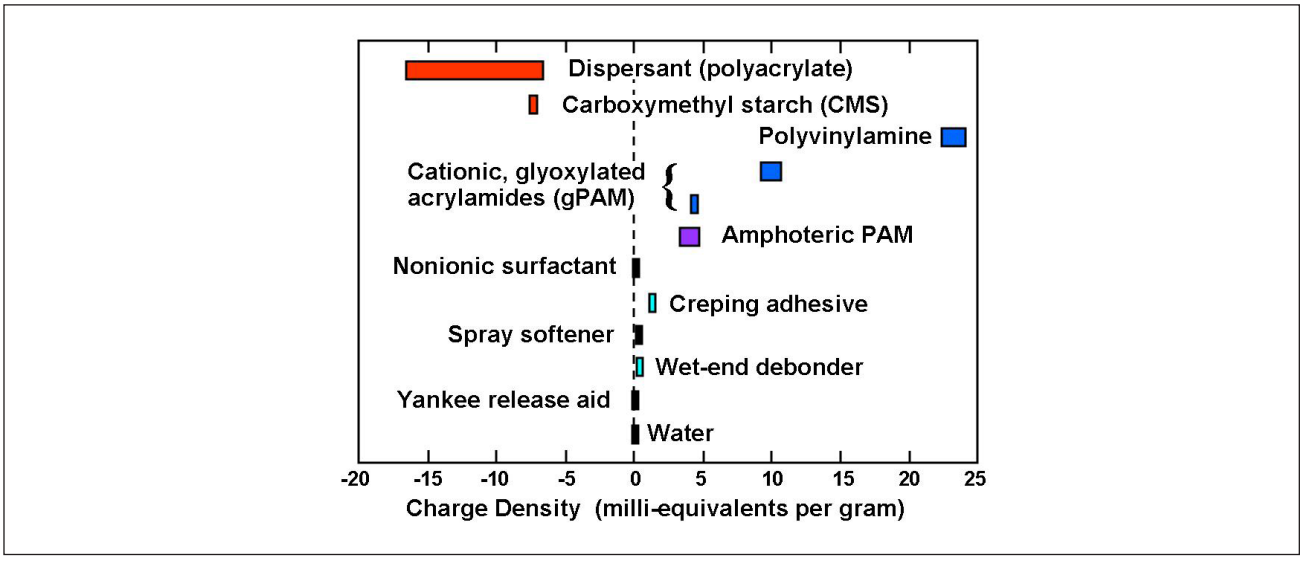
In contrast to the lack of large effects seen with the additives mentioned previously, the anionic CMS made the zeta potential less negative when added at high concentrations. This suggests that the CMS had a lower charge density and moved the hydrodynamic slip plane further from the fiber surface. When the amphoteric polymer was added at high concentrations, it tended to neutralize the zeta potential, which was expected. The term amphoteric means that the polymer had both positive and negative ionic groups. The medium and high charged cationic strength resins increased the positive zeta potential when added at higher concentrations. However, for lower dosages, there was more variation in the results.

Charge demand properties

Of the additives tested, many did not contribute a significant amount of titratable charge when compared to the highly charged additives. Therefore, most of the discussion here will revolve around the additives having a strongly charged nature. Results are shown in **Fig. 6**.

The highly anionic strength agent and low-mass polyacrylate dispersant, as well as the CMS, both contributed a significant effect on the charge density, adding to the cationic demand. Although the dispersant gave more negative values of charge density, the tests had poor reproducibility.

In contrast to the previously mentioned additives, the polyvinylamine, amphoteric polymer, glyoxylated polyacrylamide, and creping adhesive all had a net positive effect on the charge density. The amphoteric polymer was expected to be net cationic, since it is intended for papermaking applications. The polyvinylamine had a remarkably high cationic charge under the conditions of testing. It was



6. Charge density of tissue-related additives based on polyelectrolyte titrations to a streaming current endpoint.

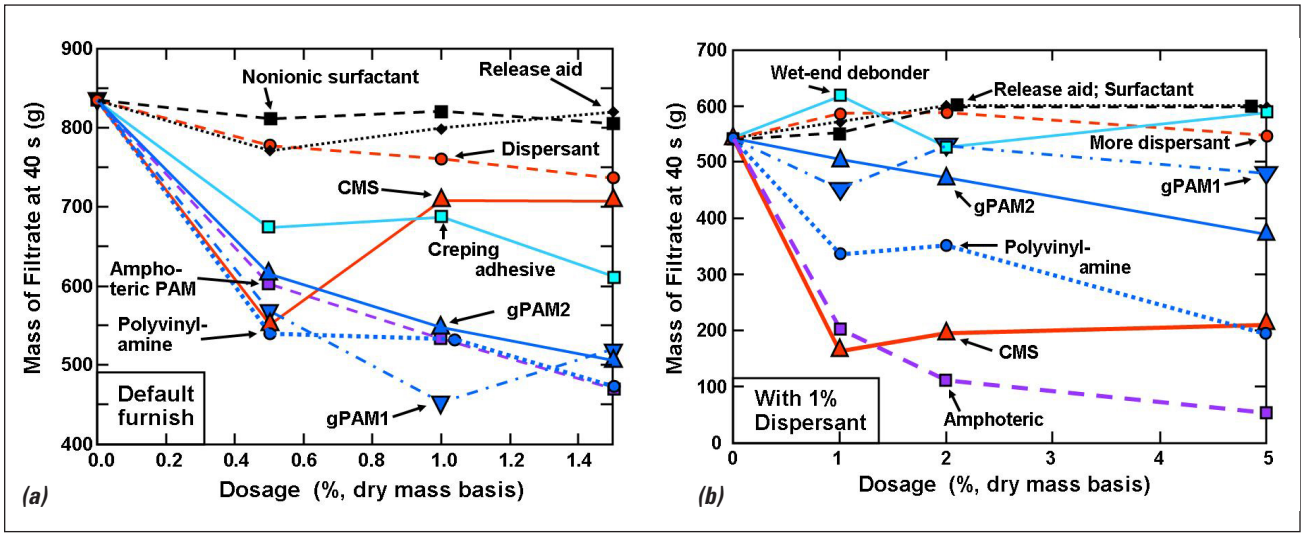
expected that the effective charge would be lower, due to deprotonation of the amine groups with increasing pH. However, due to its molecular structure, polyvinylamine starts out with a very high charge density at mildly acidic pH values. Past work pertaining to a related chemical (polyethyleneimine) suggests an approximately linear decrease in zeta potential up to a pH of about 8, and then a steeper decrease to neutral zeta potential and charge demand at a pH of about 10 [22-23].

Dewatering rate

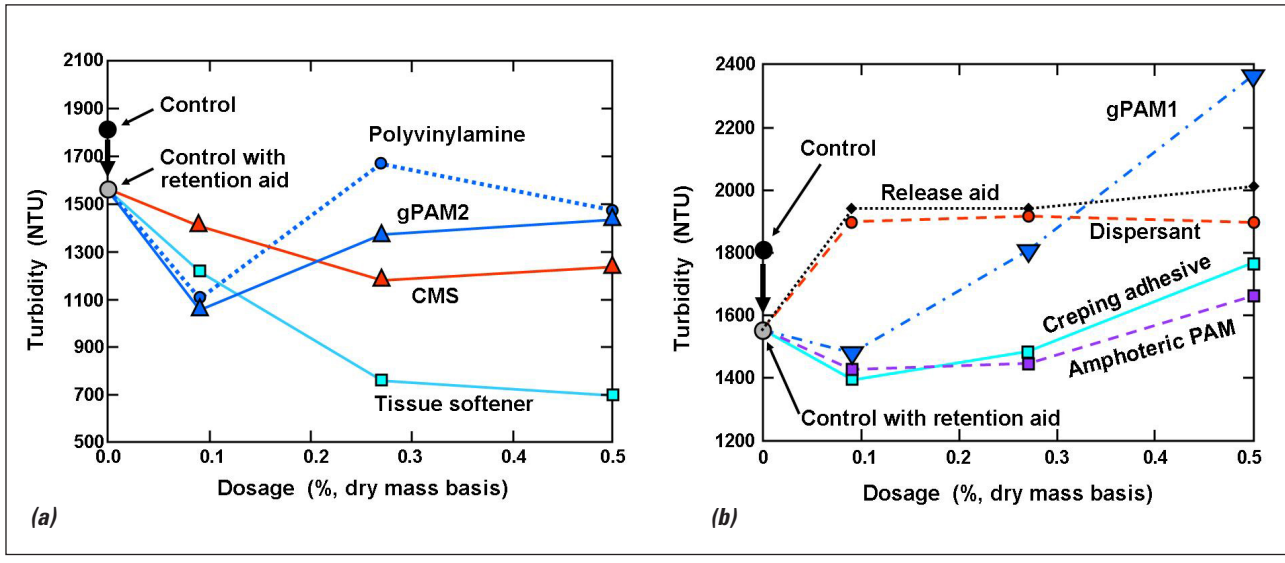
Drainage results from both the default and dispersant-pretreated furnishes had similar overarching results, with a few key differences. Results are shown in **Fig. 7a** and Fig. 7b.

For the default furnish, tissue-related additives that had a significant effect on the dewatering rate tended to hurt the drainage. These charged polymeric additives, when present in excessive amounts, tend to give a net charge to the fiber surfaces, causing repulsion and increased dispersion. A higher level of freely-floating fines, resulting from the repulsive forces, will be expected to block drainage channels more effectively.

For the furnish pretreated with 1% polyacrylate, several of the additives showed a minor beneficial effect on drainage. This may be due to a dilution effect, since the additives added more water to the system. The more interesting effect for the treated furnish was certain additives that severely hurt the drainage. This suggests that when cationic additives were put into the furnish, polyelectrolyte complexes were formed, and they acted like fines. However, the results must be interpreted differently for the anionic



7. (a) Effect of tissue-related additives on the dewatering rate of recycled copy paper furnish (default condition); and (b) effect of tissue-related additives on the dewatering rate of recycled copy paper furnish (in the presence of 1% polyacrylate dispersant, by solid mass).



8. Effect of tissue-related additives on first-past retention with recycled copy paper furnish (first set of additives); and (b) effect of tissue-related additives on first-past retention with recycled copy paper furnish (second set of additives).

CMS addition. This additive may act in parallel with the effect of the dispersant rather than forming polyelectrolyte complexes. These mechanistic ideas will need to be considered in future work.

Retention efficiency

The filtrate turbidity, which is a measure of light scattering caused by unretained suspended materials, was decreased by most of the tissue additives. These effects are shown in **Fig. 8a** and Fig. 8b, which both pertain to systems pretreated with polyacrylate dispersant. In each case, the downward arrow indicates the effects of the cPAM retention aid when acting in the absence of the tissue chemicals. Thus, the cPAM had the expected effect of increasing the retention efficiency. However, the opposite effect was observed for the release aid, the dispersant, and some of the cationic polymer additives at their higher dosage levels. These latter effects are symptomatic of overdose conditions. Based on these findings, mills that are looking to share process water between a tissue machine and another paper machine may inadvertently introduce retention issues to the process.

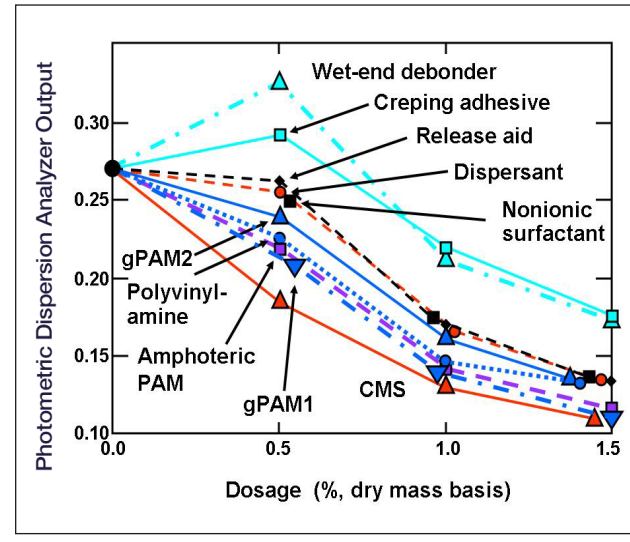
Parallel results, obtained for the default furnish in the absence of dispersant, can be summarized as follows: in general, cationic additives such as gPAM and the creping adhesive favorably affected retention only at the lowest addition level (0.09% on a solids basis), while higher levels gave progressively higher filtrate turbidity values. By contrast, the anionic dispersant was unfavorable to retention at all levels of addition when added to the default furnish. The amphoteric PAM, which can be regarded as a weakly cationic additive, had little effect on the retention results in the absence of dispersant. These findings are consistent with the expected charge-based interactive forces.

Fiber flocculation

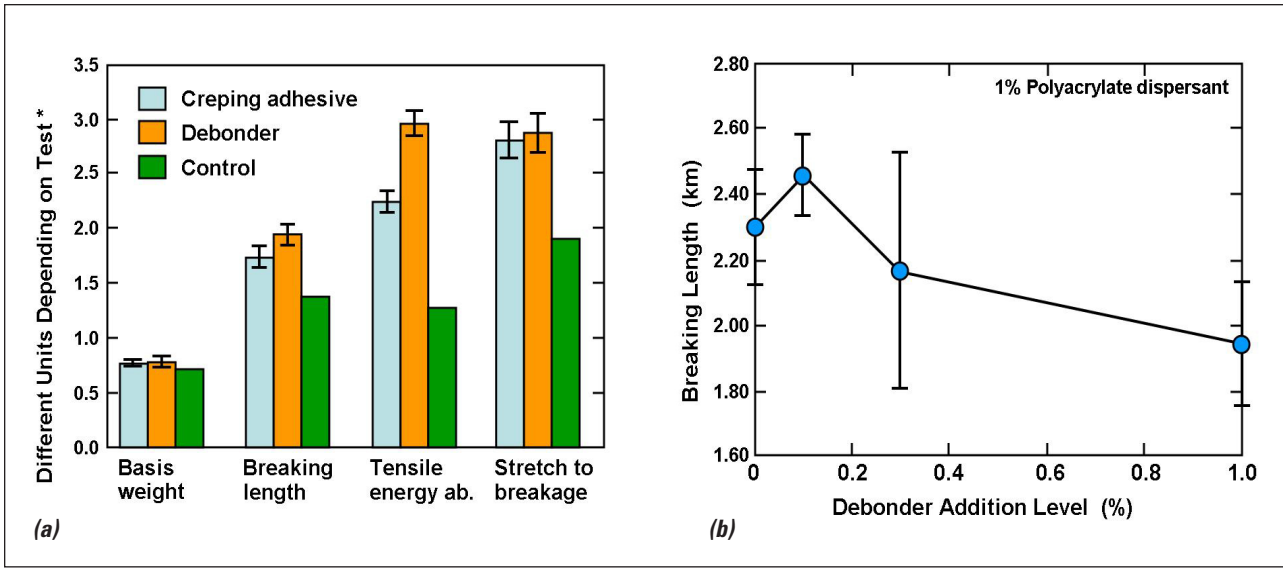
As can be seen in **Fig. 9**, there seemed to be a general decrease in flocculation with increasing additive dosage. In other words, the results suggest a general dispersant effect of each of the additives considered, especially at higher levels of treatment. Contrary trends at the lowest treatment level (0.5%) were observed for the wet-end debonder and the creping adhesive, which instead gave a flocculation effect. Based on Fig. 6, these two additives can be described as having a slightly positive cationic charge and a relatively low molecular mass.

Handsheet properties

Significant effects on measured physical properties of the resulting paper were observed for two of the studied addi-



9. Effect of tissue-related additives on the flocculation extent of recycled copy paper furnish.

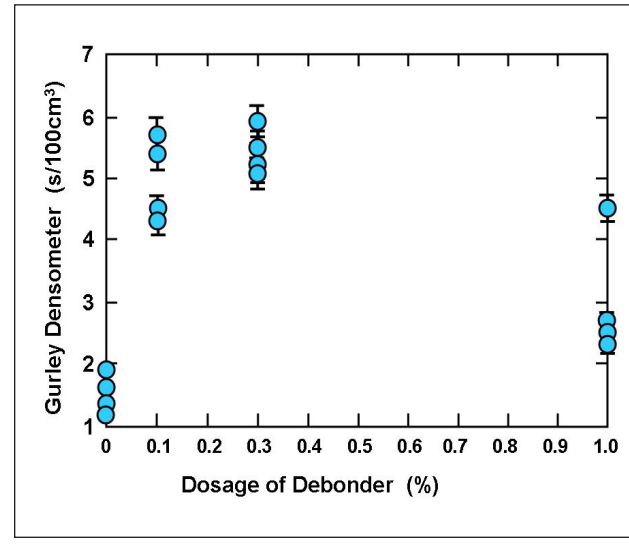


10. (a) Effect of various tissue additions, all at the 0.1% level based on solids, on some properties of handsheets prepared from 100% recycled copy paper furnish; and (b) effect of the addition level of debonding agent on the breaking length of handsheets prepared from 100% recycled copy paper furnish. Units on the vertical axis include: basis weight (100 x g/m²); breaking length (km), tensile energy absorption (100 x J/m²); and stretch to breakage (percent).

tives, the creping adhesive and the debonding agent. These effects are shown in **Fig. 10** for 0.1% level of treatment. As shown in Fig. 10a, the additives increased the breaking length, tensile energy absorption (TEA) and stretch to breakage relative to the control. The greatest relative increases vs. the control tests at the 0.1% addition level were observed for the TEA results, which take into account both tensile forces and stretching. The basis weight of the sheets was the only tested parameter not significantly affected by the addition of adhesive or debonder.

Debonding agents are expected to work by blocking the formation of some of the hydrogen bonding between adjacent fibers [7]. However, as just shown, the opposite was found at the 0.1% treatment level. To help clarify these unexpected effects, tests were carried out at increasing levels of the debonding agent. Figure 10b shows results for the breaking length for furnish that had been pretreated with dispersant at the 1% level. Even though a minor increase in the paper's tensile strength was observed at 0.1% addition of the debonder (which was significant at the 80% level of confidence), decreases were observed at higher levels of addition. In particular, at the 1.0% addition level, the decrease in breaking length was highly significant ($p = 0.005$).

In an effort to shed further light on the effects of the debonder, **Fig. 11** shows results for Gurley densometer porosity testing. As shown, relatively low amounts (0.1% and 0.3% levels) made the paper less porous (higher seconds). A likely explanation is that the cationic charge of the debonding agent increased the retention of cellulosic fines by a filtering mechanism. Such fines, due to their high flexibility and small size, might fill up void spaces in the paper. The fact that the effect reversed itself at high debonding



11. Gurley densometer seconds as a function of debonder dosage for the same sheets considered in Fig. 10.

agent level (1.0%) is what would be expected for an excess of cationic charge, thus leading to worsening retention of the fines.

DISCUSSION

A big take-away message from this work, in which various tissue additives were added to copy paper furnish, was that surface charge issues, including zeta potentials and titratable colloidal charge, were greatly affected by some of the tissue additives. The strength agents, such as the gPAM products, had especially notable effects on zeta potentials, often changing their values to positive within the range of dosages considered in this work. Relative to cationic de-

mand determinations, the most influential additives were again the charged polymers. An anionic dispersant (polyacrylate) and CMS were the most influential in contributing to cationic demand, whereas the cationic polymers (especially polyvinylamine) had the opposite effect.

Charge effects were particularly evident in the measurements related to retention. Notably, the lowest turbidity values were achieved at the lowest dosage tested (0.1%) for the various cationic additives, including strength agents. Lower retention was observed at higher doses of these same agents, which is consistent with an expected reversal of the system charge to a net positive state. This interpretation is backed by the results from flocculation tests, which indicated a weak maximum of flocculation at the lowest levels of the cationic debonding agent and the cationic creping agent, but a predominant dispersing effect of all of the additives with increasing addition levels. Thus, most of the results of flocculation testing (which considered dosages in the range of 0.5% to 1.5% based on furnish solids) showed a net dispersing effect, which increased with increasing dosage. This is what would be expected for surfaces covered with an excess of cationic polymer, leading to net repulsion between the particles in the suspension.

Another unexpected lesson that appeared to come from the present work was the dominant role seemingly played by agglomeration effects. The furnish employed in the present work, containing a substantial amount of $CaCO_3$ filler as well as cellulosic fines from refining, can be expected to interact in hard-to-predict ways with different chemical additives. Some earlier work had suggested that when cationic polymers have a main effect of retaining fine particles onto fibers, then one usually can expect an increase in dewatering rates [24]. The fact that most of the results in Fig. 7 were opposite to this expectation suggests that another interaction may have been dominant. Specifically, it appears that the cationic strength resins may have been predominantly agglomerating cellulosic fines, fillers, and polymeric substances into a form of fines that tended to plug up drainage channels within the wet web during paper formation. The combination of relatively high cationic charge density and intermediate molecular mass of the strength agents studied in this work leads to the expectation of a charged-patch mechanism of agglomeration of fine material in suspension [25]. Since the present evidence to support such a mechanism is indirect, there is a need for follow-up study.

Neither a creping adhesive nor a debonding agent added to the furnish is intended to increase the strength of paper. The fact that both of these effects were observed at the 0.1% addition to the default furnish suggests that there must have been an interaction effect. It is well known that paper strength decreases with increasing inorganic filler [26-27]. It is also known that paper strength decreases with increasing fiber flocculation [28]. Thus, it is tentatively proposed that these two additives had net effects of decreasing the retention of filler and increasing the uniformity of the paper, as a result of their dispersant action. The debonding agent, which is essentially a cationic surface-active agent, would be expected to have a dispersing effect if present at a sufficiently high level. Figure 7b showed that it had little effect on drainage. Further study will be needed to determine the reason why a 0.5% level of addition of the debonding agent yielded increased strength (Fig. 10) and increased flocculation (Fig. 9). Tentatively, these results might have been due to changes in either the filler content or the formation uniformity of the handsheets, neither of which was measured directly in the current work.

A further question of interest to papermakers is whether the hydrodynamic shear conditions utilized in laboratory work are chosen well enough so that the results can be reliably used to make predictions about full-scale papermaking outcomes. Such questions will be explored more deeply in future work.

CONCLUSIONS

The addition of a range of chemical additives commonly employed in tissue manufacturing had various effects when added at different levels of furnish obtained from 100% recycled copy paper. In the case of medium-charged and high-charged polymeric additives, there were notable changes in the charge demand of the furnish, as expected. However, many other effects were unanticipated. For instance, most of the additives, especially when present at relatively high levels in the furnish, adversely affected dewatering rates. Though relatively low levels of polymeric additives usually contributed to fine particle retention, higher levels interfered with the work of the retention aid. Among the tissue additives, only the wet-end debonding agent and the creping adhesive contributed to fiber flocculation, and then only at the lowest level of testing. The predominant effect of all of the tissue additives, when present at sufficient levels, was to disperse the suspension, leading to lower flocculation. Effects of the tissue additives on paper strength were especially notable with the creping adhesive and wet-end debonder, both of which increased paper strength at the lowest additive level considered.

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Papermaking process engineers can face a variety of challenges, including unexpected interactions between different chemical additives to the process. Expansion of tissue and towel production to mill sites not previously dealing with such products brings the possibility of cross-contamination with production of other paper grades. Partial sharing of process water systems, for instance, can affect both the papermaking process and the attributes of the paper product.

This study is the first time that an article has considered adding a range of different tissue additives to furnish in preparation of a different grade of paper. Due to possible interaction between several different substances present in papermaking furnish, it can be a challenge to interpret experimental findings. This challenge was met by carrying out several complimentary tests. While we did not expect a debonding agent to increase the strength of the paper, it apparently interacted with other substances to decrease filler content and to disperse the material, giving better formation.

Several undergraduate students helped complete this study. The experience provided them with insight not only into the technology, but also into publishing their work.

The current study benefits many papers mills that are evaluating tissue additives for the first time. As a next step, several related research papers are planned based on research being carried out this year.

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