PEER-REVIEWED PAPERMAKING

Drainage and retention improvement with talc

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ABSTRACT

Papermakers always welcome any improvement in drainage because it also improves machine productivity. Drainage is particularly important on machines that have limited drying capacity. A slow draining stock limits the speed at which a paper machine can be run. It can also limit the extent of pulp refining necessary for paper strength improvement. Additionally, any improvement in retention or reduction in retention aid use helps paper formation, by reducing floc size and in other ways. This is especially important in printing papers.

This paper presents laboratory results of studies on supercalendered and coated freesheet papers, which showed significant improvements in retention and drainage when talc was partially substituted for either clay or precipitated calcium carbonate (PCC). The combination of talc's low anionicity, high hydrophobicity, and large particle size improve machine drainage. Additionally, the large platy talc particles in the filler blend increased fiber and filler retention.

Application: Talc's positive effects on drainage and retention, and its functional synergy with clay or PCC, can be used to enhance a host of paper properties.

The papermaking process essentially consists of forming a web of cellulosic fibers from a dilute pulp suspension and drying it to a target dryness. Basically, it is a water removal process from the forming zone of the paper machine to the dryers. As an example, for every 100 tons of paper produced at the target sheet moisture of 7% and at a headbox consistency of 1%, 9300 tons of water has to be removed. Obviously, substantial cost is associated with water removal, which becomes more expensive toward the pressing and drying sections. As such, the strategy should be to remove as much water as possible when the web is being formed, before the paper reaches the press and the dryer section.

Cost savings with a dryer sheet leaving the wet end of the paper machine is just one part of the story. Equally important are the benefits derived from good water removal for better sheet consolidation and for better paper properties. As water is being extracted in the sheet forming zone, the cellulosic fibers are intricately brought closer to each other and eventually consolidated into a matrix which, when dried, is paper. The resultant paper properties depend to a large extent on the intrinsic pulp fiber strength, degree of fibrillation, sheet consolidation, the wet-end additives, and other factors. It is a complex mechanism involving the interaction of several parameters [1, 2]. Undoubtedly, good water removal helps improve manufacturing costs.

Associated with drainage is retention. The fibers and additives (including fillers) added at the wet end should also be retained in the paper, to the greatest extent possible without adversely affecting sheet formation and other paper properties. Flocculants can significantly boost retention, but they can also impair sheet formation when used in excess. The use of a substantial amount of fillers in supercalendered and coated papers, for example, further complicates the issue. Fillers, owing to their small size compared to fibers and because they do not fibrillate like fibers, are more difficult to retain. Any means therefore for increasing drainage and retention will be of tremendous help to papermakers. This is especially true if it does not entail the use of more retention or drainage aid and more importantly, if in so doing, some paper properties are enhanced. This is the subject of this research, where talc has been partially substituted for clay or precipitated calcium carbonate (PCC), enhancing drainage, retention, and some paper properties.

Why talc, and what is talc?

Talc is a white, soft hydrophobic mineral with a hydrous magnesium silicate structure. It is composed of three layers: a magnesium oxide or brucite layer sandwiched between two silica layers. Unlike other layered silicate minerals, such as clay, the three layers in a talc crystal are in perfect electrical balance, resulting in a mineral that carries little or no electrical charge. This lack of charge makes talc a nonpolar or hydrophobic mineral that prefers to attach itself to other hydrophobic substances such as stickies and wood pitch. This explains why papermakers widely use talc as a pitch and stickie control agent [3, 4, 5].

Table I shows the differences in properties among talc, clay, and PCC. **Figure 1** shows the differences in morphology. Talc is the softest mineral found in nature, and as such, it extends the useful life of doctor blades, slitters, and other equipment. Because of its platiness, with an aspect ratio of 30, talc can reduce sheet surface roughness for better printability and ink and coating holdout. Chemically, talc is inert and does not interact with the wet-end additives. Additionally, talc does not affect the wet-end charge of the paper machine, unlike cationic polymers. Filler talc's particle size is large, about 3 to 5 times that of clay and PCC. As such, it is easier to retain, and it assists in the retention of clay and PCC when blended with them. Being hydrophobic, talc can also enhance drainage. However, few are aware of the drainage and retention benefits that talc offers and its synergistic effect with either clay or PCC in filler applications. Mill trials demonstrated the drainage and retention benefits and the synergy of talc, which confirmed the results of our laboratory studies. Because of the confidentiality of mill trials, only laboratory results are presented and discussed in this paper.

EXPERIMENTAL

Commercial paper mills provided the pulps and wet-end additives used in our experiments. A laboratory vacuum drainage tester was used. The set-up consisted of an Erlenmeyer flask with a side adapter fitted with a Buchner funnel. We attached a hose with a vacuum gage to the flask and connected the hose to a vacuum source. The retention work employed a Britt jar using a 100 mesh screen. For drainage and retention studies, we prepared sufficient 1% pulp slurries to simulate headbox consistency. The pH of the slurries was then adjusted with dilute sulfuric acid or caustic. Both drainage and retention studies used a 500 g slurry at 1% consistency replicated twice for each treatment. The required amount of additives were measured, added, and dosed in the sequence practiced by the mill.

In the drainage study, we recorded the following data:

a) time required to collect 400 mL of the filtrate, indicative of initial drainage at the forming end of the paper machine;
b) maximum vacuum, which represents couch vacuum, and
c) vacuum at 2 minutes, indicative of the dryness of the sheet as it leaves the couch for the press.

In some cases, the dryness of pads was determined by computing the ratio of the oven-dry weight of the pulp in the pad to the wet pulp weight (i.e., weight of the pulp at 2 min draining time).

In the retention study, about 55 g of the slurry was collected immediately after the pinch-cock was opened. The collected slurry was weighed, filtered through a Buchner funnel, and dried in an oven at 105°C. Pad consistency (white water consistency) was determined. Retention was computed as follows:

Retention = ((headbox consistency – white water consistency)/headbox consistency) x 100

We used the computerized MK machine to make handsheets. Mill conditions in terms of wet-end additives dosages and order of addition were followed. Supecalendering, if required, was done using a Perkins laboratory supercalender at the following conditions: 1350 psi, 4 nips, and 140°C. roll temperature. The handsheets were conditioned for at least 24 h in a temperature-humidity controlled room before testing using TAPPI standard conditions.

RESULTS AND DISCUSSION

SC Paper

Table II shows the drainage results obtained by partially substituting talc for clay in a pulp furnish for supercalendered paper production. The results show that blending clay with various talcs of different particle size and morphology significantly improved drainage and pad solids. Talcs labeled MT and N are microcrystalline; talc labeled PT is macrocrystalline. The results are graphically presented in **Figs. 2-5**.

Drainage time (Fig. 2) and dryness (Fig. 3), as indicated by pad solids, were found to be a linear function of talc median particle size. Substituting 20% of clay with talc resulted in a 2.5-3.5 percentage points increase in pad dryness, depending on the talc particle size used. The result can be interpreted in the following ways:

1) Machine speed can be increased resulting in more paper production; or in dryer-limited machines, it can provide a buffer in terms of drainage spikes caused by wet-end paper machine upsets.
2) Machine speed stays the same, but the mill can reduce its use of retention or drainage aids, resulting in cost savings.

In addition, the reduction in retention aid use can improve paper formation and the paper properties associated with improved paper formation. It can also improve the printing performance of the finished paper.

The dryness of the pad (Fig. 4) was linearly and inversely related with the vacuum reading at 2 min. The maximum vacuum or "pull" that occurs at the early stage in the dewatering process was found to be unrelated to the vacuum at 2 min (Fig. 5).

With the drainage improvement obtained with furnish A in the SC application, the study was expanded to include retention using a different furnish. The effect of talc morphology, hydrophobicity, and quantity of talc in the blend was also studied. **Tables III-VI** show the results.

Effect of particle size on drainage and retention—furnish B

Similar to the results seen in furnish A, talc plays an important role in enhancing drainage and retention (Table III). The 7.2 μm talc increased drainage by 26% and improved retention by 4.2 percentage points.

Effect of morphology (macro vs. micro) on drainage and retention—furnish B

Table IV shows the effect of talc's morphology on drainage and retention. The macrocrystalline talc, owing to its shape, was expected to enhance drainage and retention more than a microcrystalline talc. In this study, only very slight and insignificant gains in drainage and retention were seen with the macrocrystalline talc. It is likely that the 5 μm MPS is not large enough to measure significant differences between a microcrystalline and macrocrystalline talc in terms of retention and drainage.

Effect of hydrophobicity (chlorite) on drainage and retention—furnish B

Some talc ores contain a substantial amount of chlorite. The presence of chlorite in talc makes talc less hydrophobic, which may retard drainage. Table V shows that 20% chlorite in talc had no appreciable effect on drainage and retention.

Effect of talc in the blend on drainage and retention—furnish B

More talc in the clay-talc blend (Table VI) resulted in faster drainage and higher retention. A 3% talc substitution brought minor improvement in drainage and retention. The significant improvements were seen at 5% talc substitution, and even more so at 7% talc substitution.

Talc's synergy with PCC and with clay in SC papers

Table VII shows some interesting results obtained by substituting talc for PCC in a supercalendered paper furnish. Gloss, porosity (closer sheet), rotogravure printability (Heliotest), tensile, formation, and drainage were significantly improved. The large, platy talc particles, when mixed with the bulky PCC, closed the sheet structure and improved sheet formation. As expected, because of talc's lower brightness and its large particle size, sheet brightness and opacity were reduced. The reduction in coefficient of friction with talc can be beneficial for papers where high coefficient of friction is the cause of crepe wrinkles and core bursts in printing presses.

Table VIII presents the results of blending talc with clay. Significant improvements in tensile, rotogravure printability (higher Heliotest values), and machine drainage were seen.

The tensile improvement derived from incorporating talc in both PCC and clay applications results from talc's larger particle size and morphology compared to either PCC or clay. For a given weight of filler, talc has fewer particles that interfere with fiber-to-fiber bonding, resulting in strength improvement.

Coated base paper application

Tables IX and **X** show the effects on drainage, retention, and paper properties of a coated base paper when replacing some of the PCC with talc. At 2% substitution, talc had a noticeable effect on drainage, but not on retention. A 4% PCC replacement with talc was necessary to attain meaningful drainage and retention enhancements. A substantial improvement in drainage over control was still attainable at 2% more total filler (i.e., from 15% to 17%), without an increase in retention aid usage. Retention at this higher filler level was the same as that of the PCC control.

The paper properties in Table X show some interesting results. Tensile and porosity were affected positively, but not brightness. The reduction in brightness by replacing 4%

PCC with talc was expected because of the lower brightness of talc pigment compared to PCC. However, the lost brightness is regained by increasing total filler from 15% to 17%. At the 17% filler level, the sheet tensile and porosity were higher than the PCC control. This means a possible cost savings by replacing the more expensive kraft pulp fibers with talc. Concomitant with that are the benefits of faster drainage and higher tensile and a closer sheet structure.

CONCLUSIONS

Talc's partial substitution for either clay or PCC in supercalendered or coated base paper furnish enhanced drainage and retention. It also improved some paper properties, notably tensile and rotogravure printability.

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INSIGHTS FROM THE AUTHORS

Papermakers are always under pressure to increase production; therefore, strategies to increase machine speed and improve drainage will greatly help them. Previous research indicated some improvements in machine drainage with talc as a side benefit, but such research was very limited in scope. This study has a wider coverage that includes talc morphology, degree of hydrophobicity, and fiber/filler retention as well.

The choice of the drainage tester to use that would simulate paper machine drainage was the most difficult part of our research. During the study, the synergy of talc with PCC and clay in paper properties improvement, as well as the linear relationship between drainage time and talc median particle size, proved very interesting. What was surprising was that morphology and chlorite content in talc did not impact drainage, contrary to our expectations.

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Table I. Filler Properties (6, 7,8)

Properties	Talc	Clay	PCC
Mineralogy	Mg-silicate	Al-silicate	Calcium carbonate
Morphology	Macrocrystalline	Blocky	Scalenohedral
Refractive Index	1.57	1.56	1.66
Surface Energy (mJ/m^2)	35-40	55-60	75-80
Particle size, D50 or MPS (μm)	5-7	1.5	1.3
GE Brightness (%)	83	81	98
Moh's Hardness	1	2	3
Aspect ratio	30	15	1

Talc **AT-PCC** **Clay**

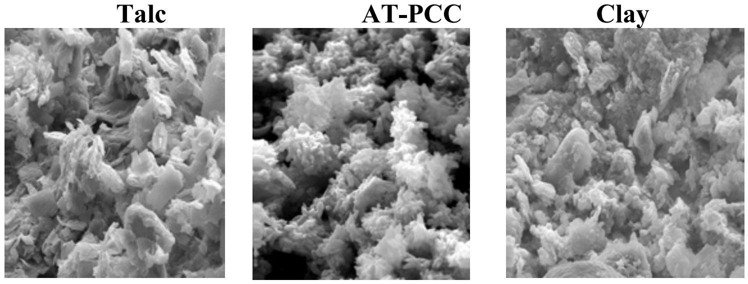

Fig. 1 SEM's of Talc, Clay and $CaCO_3$

Table II. Drainage of Clay and Clay/Talc Blends (Furnish A)

Treatments (25% Total Filler)	Drainage Sec/400 mL	Max Vac In. Hg	Vac. At 2 min. (In. Hg)	Pad Solids %	Median Particle Size (MPS), μm
Clay alone	83	22.5	22.2	21.2	1.8
Clay/MT5 (80/20)	56.6	22.5	19	23.74	5
Clay/MT6 (80/20)	50	21.2	17.8	24.7	5.9
Clay/MT7 (80/20)	49	21.2	17.6	24.77	7.2
Clay/N5 (80/20)	56.2	22.1	18.2	24.1	4.9
Clay/PT5 (80/20	51.3	22.2	17	24.75	5.1

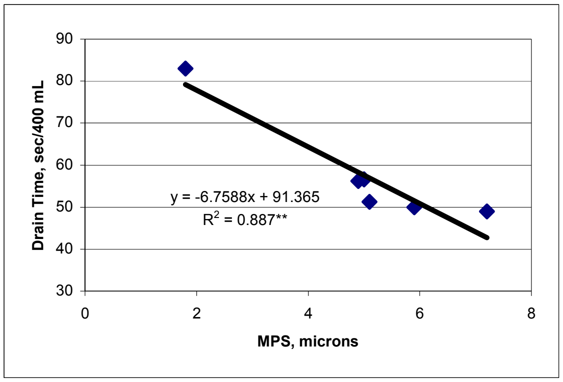

Fig 2. Drainage Time vs. Talc Particle Size

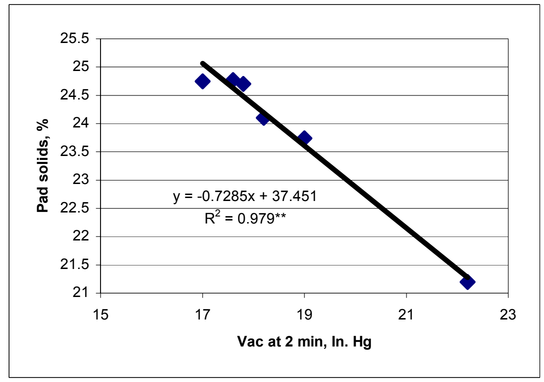

Fig 4. Pad Solids vs. Vacuum at 2 min.

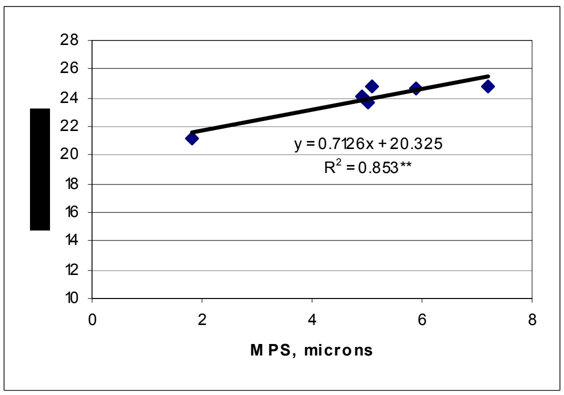

Fig 3. Pad Solids vs .Particle Size

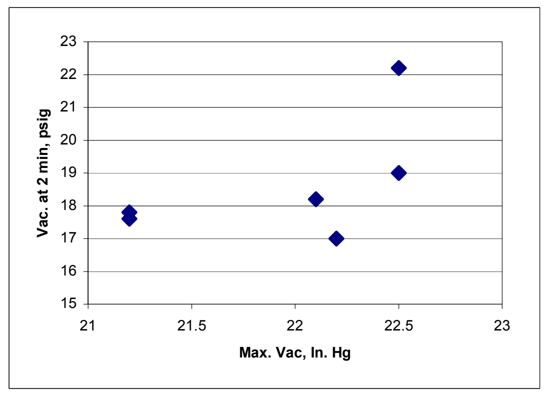

Fig 5. Vac. At 2 min. vs. Max Vac.

Table III. Drainage and Retention with Talc of Different Particle Sizes

Talc in Clay/Talc Blends (80/20)	Drainage sec/400 mL	Retention %
Clay (Control)	49.0	86.6
MT 5	44.8	88.7
MT 5.9	38.4	89.3
MT 7.2	36.1	90.8

Table IV. Drainage and Retention with Talc of Different Morphology

Talc in Clay/Talc Blends (80/20)	Drainage sec/400 mL	Retention %
MT5 (Micro)	44.8	88.7
PT5 (Macro)	43.0	88.8

Table V. Drainage and Retention with Talc of Different Hydrophobicity

Talc in Clay/Talc Blends (80/20)	Drainage sec/400 mL	Retention %
MT5	44.8	88.7
MT5/Chlorite (20% Chlorite)	45.6	88.5

Table VI. Drainage and Retention at Different Addition Levels

Talc/Clay		Drainage sec/400 mL	Retention %
Talc (MT5)	Clay		
0	25	49.0	86.6
3	22	47.0	87.2
5	20	44.8	88.7
7	18	39.1	90.4

Table VII. SCA Paper Properties of PCC/Talc Blends (Furnish C), (9)

Properties	PCC Control	4% Talc	8% Talc
Basis weight, gsm	51.5	51.3	51
Gloss, %	28.1	30.1	32.3
Opacity, %	96.2	95.7	95.4
Brightness, %	65.2	64.4	63.3
PPS Porosity, mL/min	125	102	89
Static COF	0.68	0.56	0.58
Kinetic COF	0.64	0.49	0.51
Heliotest (mm)	11	15	17
Tensile (BLM)	2000	2100	2200
Formation Index	33	45	44
Drainage, sec/400 mL	13	11.9	10.4

Table VIII. SCA Paper Properties of Clay/Talc Blend (Furnish D), (9)

Properties	Clay Control	4% Talc	8% Talc
Basis weight, gsm	50.8	50.4	50.6
Gloss, %	26.8	26.7	26.3
Opacity, %	93.8	94.6	93.3
Brightness, %	60	59.5	61.1
PPS Porosity, mL/min	88.7	90.2	89.1
Static COF	0.346	0.345	0.346
Kinetic COF	0.285	0.273	0.262
Heliotest, mm	45	51	55
Tensile (BLM)	1538	1643	1610
Drainage, sec/400 mL	53	42	38

Table IX. Effect of Talc on Drainage and Retention (Furnish E)

Treatment	Drainage		Retention %
	sec/400 mL	% Reduction	
15% PCC (Control)	16.8	0	92.2
13% PCC/2% Talc	14.8	11.9	93.1
11% PCC/4% Talc	13.2	21.4	94.2
13% PCC/4% Talc	13.7	18.5	92.1

Notes: Retention aid (coagulant, flocculant) dosages were maintained constant. Pulp furnish is a blend of bleached SW and HW

Table X. Physical Properties of Handsheets (Furnish E)

Paper Properties	15% PCC (Control)	11% PCC/4% Talc	13% PCC/4% Talc
Basis weight, g/sq m	96.5	96.5	97.1
Caliper, mils	6.8	7	6.9
Brightness, %	80.7	79.1	80.1
Opacity, %	94.6	94.5	94.6
PPS Roughness	8.84	8.88	8.82
PPS Porosity, mL/min	1073	966	981
Tensile, N/mm	2.790	3.486	2.882