Paperboard Filling Experiences with Precipitated Calcium Carbonate (PCC) for the New Millennium

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Abstract:

The application of precipitated calcium carbonate (PCC) as the preferred filler in printing and writing papers is now expanding into other segments of the paper industry, specifically bleached paperboard and white top linerboard. The solid bleached paperboard and white top linerboard marketplaces are quite competitive at this time. Evolving end user needs in each of these product areas have resulted in crucial changes in the materials used to manufacture these grades.

Today, PCC represents greater than 80% of the total filler used by the North American freesheet producers, and continues to replace less efficient and/or more costly fillers such as clay, titanium dioxide, and ground calcium carbonate (GCC). Over the past two years, several board manufacturers have converted from acid to alkaline papermaking utilizing PCC fillers to improve quality and reduce manufacturing costs. This paper reviews the use of PCC filler in meeting these changing market demands with emphasis on actual mill experience in North America.

Introduction:

The application of precipitated calcium carbonate (PCC) as the preferred filler in printing and writing papers is now expanding into other segments of the paper industry, specifically bleached paperboard and whitetop linerboard. The market for both solid bleached paperboard and whitetop linerboard is in a state of transition. Evolving end user needs in each of these product areas is resulting in significant changes in the materials used to manufacture these grades.

Solid Bleached Paperboard

The solid bleached paperboard market is moving toward higher brightness and a bluer shade in North America. This shift is most noticeable in lightweight bleached board grades or bristols. The caliper range for these grades is typically 7 – 14 point (thousandths of an inch). This shift is also occurring in mills that produce heavier weight grades as well. The increased brightness and bluer shade is allowing mills to be more competitive in the higher brightness European coated paperboard markets (1). Some manufacturers are also offering increased sheet gloss and print gloss for differentiation. The improved gloss grades are being targeted for high-end applications such as cosmetic and frozen food cartons.

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The bleached board brightness (TAPPI) range is transitioning from 82% - 84% to 86% - 90%. Some paper mills are also improving gloss at the same time, with Hunter gloss values moving from 55% - 65% to the 65% - 70% range.

North American producers of bleached paperboard have traditionally run their machines under acid wet-end conditions of pH 4.5 – 5.5. The need to achieve continuing higher brightness specifications has led to using calcium carbonate in the coating. This has caused runnability issues on the paper machine from the acid/base reaction that occurs when calcium carbonate from coated broke comes in contact with the acid wet-end environment. The major problems which occur from this reaction are:

1) Foam/entrained air caused by the liberation of carbon dioxide (CO_2) from the dissolution of carbonate pigments.

2) Formation of deposits from particulate or dissolved calcium related to the use of carbonate pigments.

3) System upsets which cause sizing, retention and drainage problems as a result of calcium carbonate dissolution.

Board mills are evaluating and commercializing alkaline/PCC filler technologies to eliminate these problems while reducing manufacturing costs to remain competitive.

White Top Linerboard

The white top linerboard market is also going through a quality transition. Early white top grades were produced with only bleached fiber constituting the top ply. This resulted in a mottled surface appearance called “Mottled White” linerboard. In recent years the quality of white top grades has improved. Many mills produce what is called “full” white top linerboard. To obtain this appearance, paper producers add fillers that provide hiding power over the natural “brown” base ply. The typical fillers used include:

1) hydrous and calcined kaolin.
2) titanium dioxide
3) ground calcium carbonate (GCC)
4) silica and silicate

These fillers provide adequate brightness allowing mills to achieve typical 72% TAPPI brightness standard, but their hiding power differs greatly. Low hiding power characteristic of hydrous kaolin, GCC, and silica cause mills to use more bleached fiber than they would like while calcined kaolin and titanium dioxide are costly alternatives but do exhibit good hiding power.

White top linerboard producers are currently looking for improved brightness and appearance. A new brightness standard is currently developing and is expected to be 76% or even higher in 2000.

Higher quality graphics for these grades are evolving. Print jobs that were once one or two-color flexography are giving way to four-color flexography and offset printing. This places new demands on the surface characteristics (e.g., smoothness and porosity) of white top linerboard.

PCC Filler for Bleached Paperboard and White Top Linerboard:

The move to utilize PCC filler in bleached board grades has been fueled by a continued drive toward higher quality and increased cost reduction. The shift to alkaline papermaking technology combined with PCC filler allows board manufacturers to improve specific quality parameters, such as brightness and hiding power, which under acid conditions were impossible or too costly to achieve. The cost of paper products will need to be low to remain competitive against alternative products, such as plastics or electronic media (2), therefore, increasing quality while reducing cost is a major objective these mills strive for.

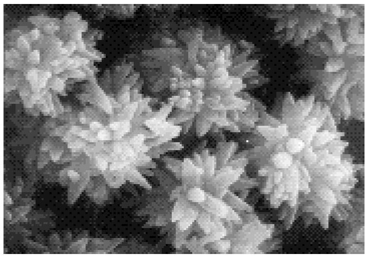
PCC fillers represent greater than 80% of the total filler used by the North American freesheet producers, and continues to replace less efficient and/or more costly fillers such as kaolin, titanium dioxide, and GCC. PCC is currently produced at more than 70 manufacturing sites worldwide with most of these sites next to paper mills. This concept of "on-site" PCC manufacture was successfully introduced in the mid 1980's and had a dramatic impact on the cost/performance equation for PCC in paper products.

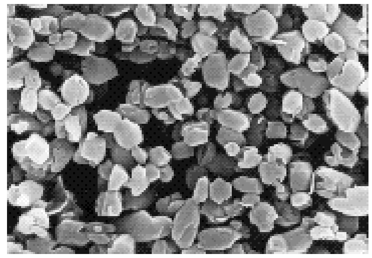
PCC that is produced at a mill site uses locally purchased lime as a major raw material. This lime is slurried (slaked) with water and then added to a reaction vessel called a carbonator. Carbon dioxide (CO_2), which is usually sourced as a by-product from paper mill operations, is fed into the carbonator, which reacts with the lime slurry to form PCC crystals. Controlling the parameters referred as "degrees of freedom" can change the physical properties of the crystals. These physical properties include:

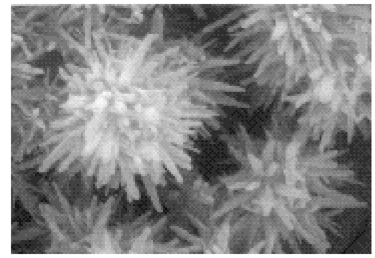
a) Particle or crystal morphology
b) Particle size
c) Surface area
d) Particle size distribution
e) Surface chemistry

Most precipitation processes inherently produce products with a very narrow particle size distribution. This offers benefits that are difficult to match by other mined and milled minerals such as GCC and hydrous or calcined kaolins.

PCC is commonly produced in two mineral forms, known as calcite and aragonite. The calcite mineral form will typically be produced in two crystal shapes, either scalenohedral or prismatic morphologies. The aragonite mineral form will typically be produced with an orthorhombic (needle-like) morphology. Scanning electron micrographs are shown below for these products.







Scalenohedral PCC *Prismatic PCC* *Clustered Aragonite PCC*

The scalenohedral – calcitic form of PCC is the most widely used for PCC for paper filling. These are high brightness families of products (96%) to 98% TAPPI, 94% to 96% ISO) that range from 0.8 µm to 2.7 µm average particle size (APS). Maximum light scattering for opacity is found at 1.3 µm APS. This form of PCC also offers sheet bulk that milled minerals cannot match economically. When produced with a 2.1 µm to 2.7 µm APS the bulking characteristic is maximized, while bond strength is optimized, and size demand is minimized. This helps paperboard mills maintain the critical stiffness and sizing at maximum filler levels.

Results:

Bleached Paperboard

Over the past two years, three bleached board manufacturers have converted from acid to alkaline papermaking utilizing PCC filler. Several more have R&D programs in place actively looking at making the technology switch. These alkaline bleached board mills are typically adding from 3% to 9% PCC with an average particle size (APS) ranging from 2.1 µm to 2.7 µm. At these filler levels, they are able to maintain or increase board bulk while balancing other critical bleached board properties. The replacement of expensive bleached fiber with PCC filler results in a significant manufacturing cost savings ranging from U.S. $3.00 to U.S. $8.00 per ton of finished paperboard (1).

Board brightness also improves by 2 points or more at these filler levels. If this is coated board, a brighter baseboard makes it easier for mills to meet their new higher coated board brightness targets.

PCC acts as a pH buffer in the bleached board wet end and provides alkalinity, eliminating the need for sodium bicarbonate. Alkaline mills have noted the wet-end is much more stable with the alkaline chemistry in place. Runnability has also improved due to fewer deposits and less foam (entrained air) compared to acid systems.

The star chart below (figure 1) shows the properties which have been achieved by one alkaline bleached board mill. Almost all of their major board properties have either improved or remained unchanged since switching from an acid to an alkaline wet-end system along with using 5% PCC filler. Even the number of days between boil-outs has dramatically improved. This benefit has been documented by other paper mills and researchers (3, 4). The natural cationic surface charge on the PCC particle gives it the ability to adsorb or tie-up pitch, stickies, and other anionic trash much like talc. This property helps promote improved paper machine runnability.

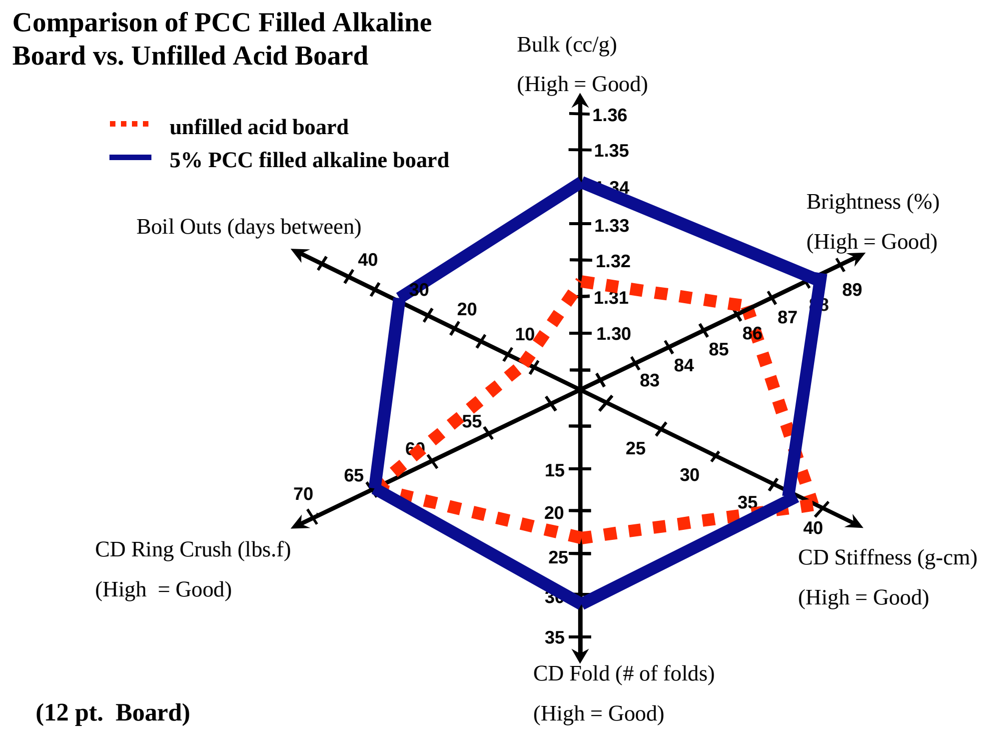


Figure 1. Comparison of PCC Filled Alkaline vs. Acid 12 pt. Board from Commercial Papermachine

Table I compares their additive and machine conditions under acid and alkaline systems.

Table I. Comparison of Acid vs. alkaline Conditions			
Acid		**Alkaline**	
Rosin	0.4%	ASA	0.12%
Alum	0.95%	Alum	0.20%
TiO_2	0 – 2.5%	PCC	4 – 6%
Corn Starch	0.20 – 0.25%	Corn Starch	0.60%
		A-PAM	0.05%
		F. P. Filler Retention	66%
Head Box pH	5.0	Head box pH	7.5

The mill has realized several benefits to date including:

a) Increase baseboard brightness.
b) Ability to increase carbonate content in their coating for brightness.
c) Less shade reversion. Inventory fading is reduced.
d) More stable wet end runnability.
e) Fiber savings through lower cost filler use.
f) The replaced fiber is used on another machine to increase its productivity.

The mill continues to optimize their board and are cautiously moving to higher PCC filler levels.

White Top Linerboard

Over the past year four white top linerboard producers have switched to PCC filler with three of the four converting from acid to alkaline technology. The fourth mill was already alkaline and only needed to switch filler.

In white top linerboard grades, the addition of a 1.2 µm – 1.3 µm average particle size filler PCC offers maximum light scattering (hiding power) as well as brightness and bulk as benefits. The appearance of the sheet can be maintained or improved, depending on whether the goal is to maximize quality or maximize cost savings.

The especially high light-scattering and brightness characteristics of this PCC allows mills to increase white top brightness while reducing bleached fiber coverage. A 42 lbs (205 gsm) white top linerboard sheet can reduce its requirement of bleached fiber for coverage by as much 5% (e.g., 36% to 31% top ply coverage). These properties are achieved through the application of 8% - 15% PCC filler in virgin bleached top ply and 5% - 10% PCC in a recycled (MOW) bleached top ply. When bleached recycled fiber is used, a combination of filler carryover and lower fiber strength limits PCC addition. Meeting the increasing industry brightness standards will become more difficult for mills using recycled fiber in their top ply.

Changing from kaolin or GCC filled white top grades to PCC filled grades opens up the sheet's porosity. This allows uniform controlled flexographic ink receptivity and results in improved print quality.

Although GCC fillers also yield good brightness and often better bond strength than the 1.2 µm – 1.3 µm PCC, even the new narrow particle size GCC fillers cannot match the value offered by PCC's fiber reduction potential. The total furnish savings realized by white top producers, more than offsets any filler price differential.

By utilizing the principles of light absorption and reflectance explained by Kubelka and Munk (5), mills can take advantage of excess brightness by dying back. This will improve opacity and may allow mills to improve white top appearance or maintain appearance with further bleached fiber reduction.

Brightness increases of 2 to 7 points can be achieved while reducing bleached ply coverage. Annual savings in excess of U.S. $2 million can be realized when PCC filler levels of 8% to 12% are reached. Figures 2, 3, 4, 5 and 6 show how brightness, appearance and percent top-ply coverage have been improved by using 1.2 µm – 1.3 µm PCC filler. Results below are from commercial experience.

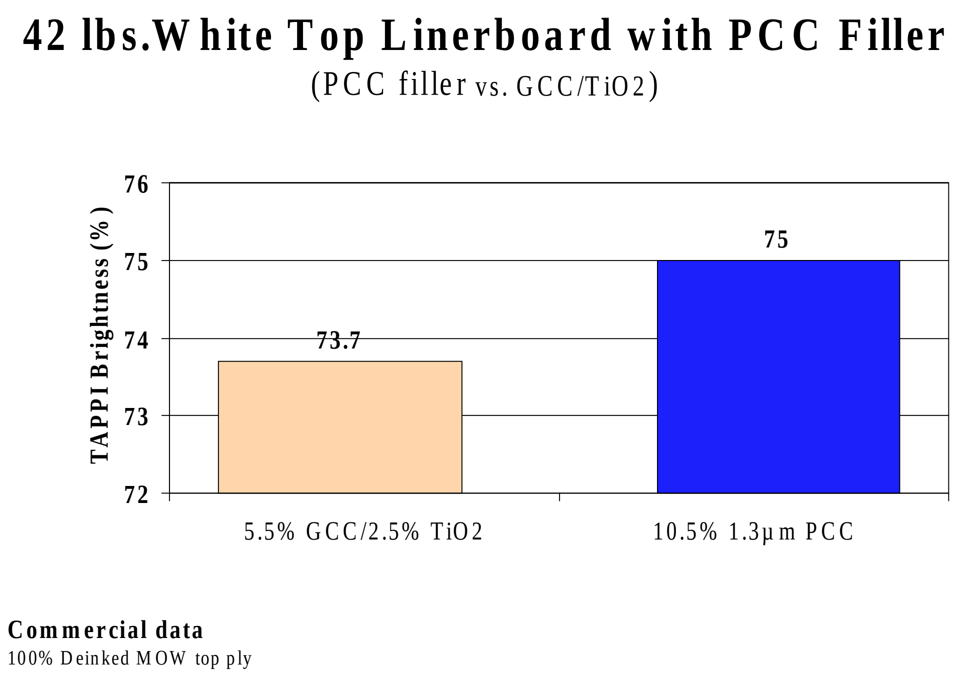


Figure 2. White Top Linerboard and Brightness Improvement Using PCC Filler for Mill #1

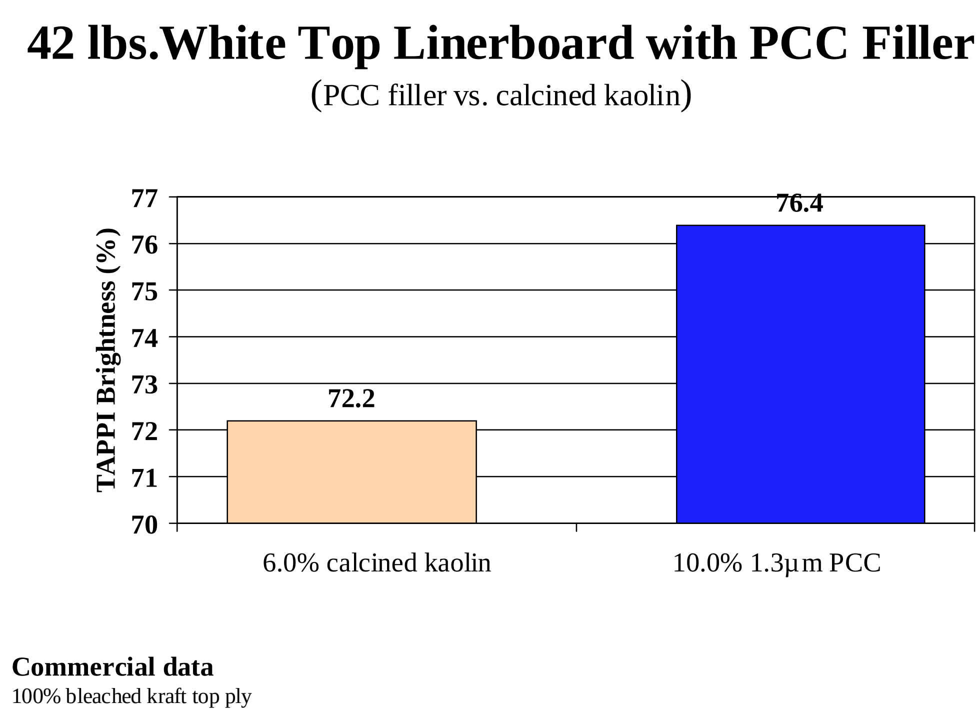


Figure 3. White Top Linerboard Brightness Improvement Using PCC Filler for Mill #2

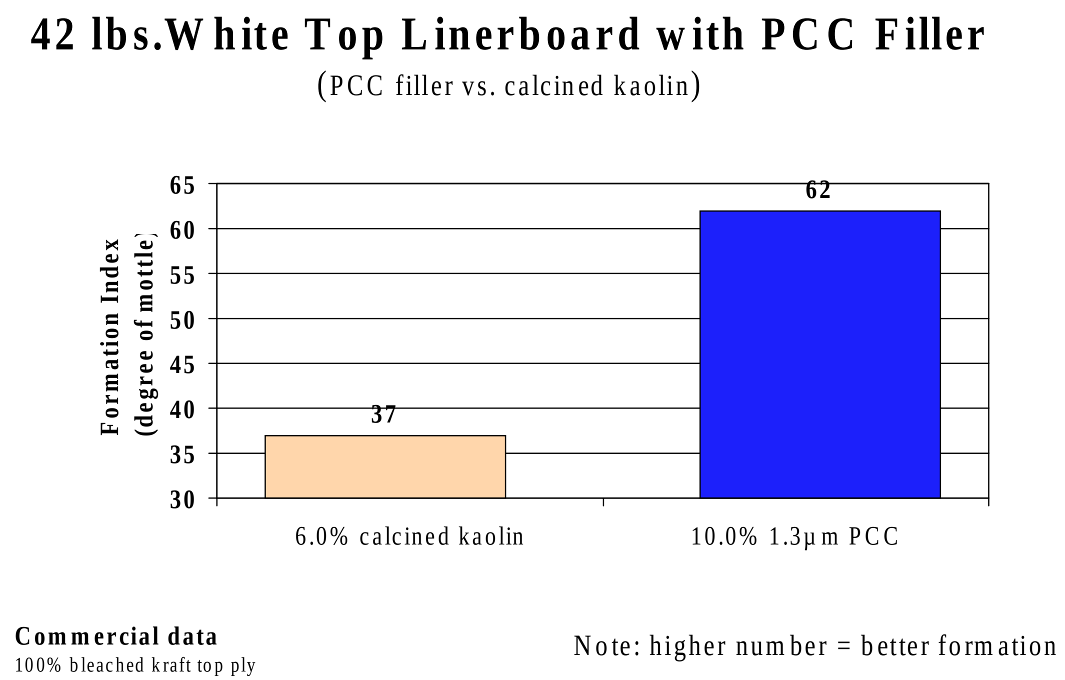


Figure 4. White Top Linerboard Formation (Appearance) Improvement Using PCC Filler for Mill #2

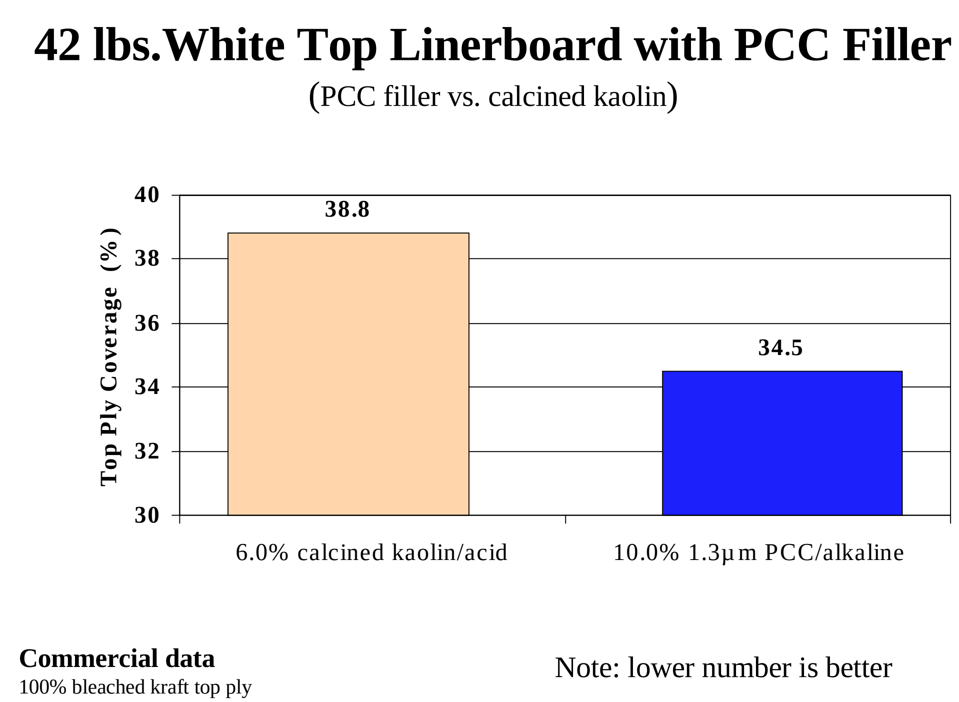
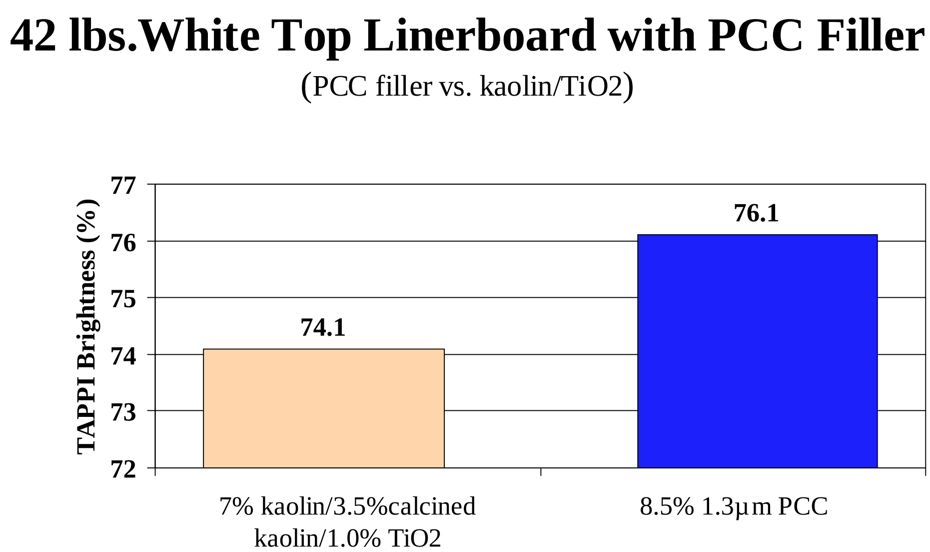


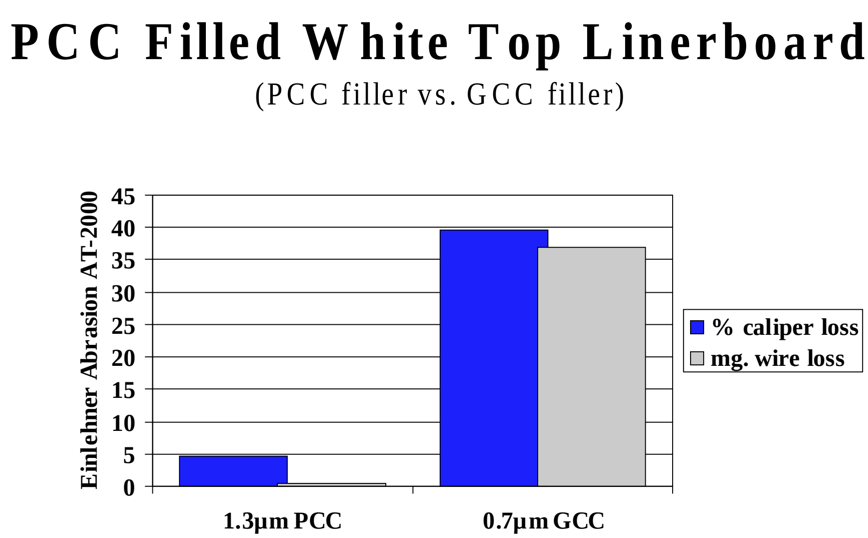
Figure 5. White Top Linerboard Top Ply Coverage Using PCC Filler for Mill #2



Commercial data
100% bleached kraft top ply

Figure 6. White Top Linerboard Brightness Improvement Using PCC Filler for Mill #3

Abrasion issues should always be considered when it comes to machine wire life and converting operations wear. Figures 7 and 8 show the abrasion characteristics of 1.2 µm – 1.3 µm PCC versus GCC filler manufactured in Southeast U.S., and calcined kaolin, respectively.



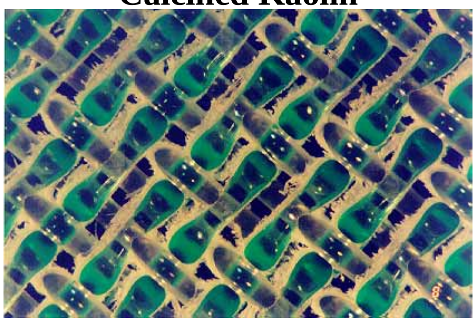
laboratory testing

Figure 7. Abrasion of PCC versus GCC for White Top Linerboard

Papermachine Wire Abrasion

(Comparison of 1.3µm PCC vs. calcined kaolin)

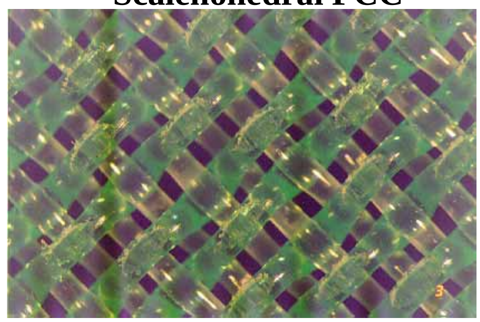
Calcined Kaolin



38.4 mg wire loss

38.5% caliper loss

Scalenohedral PCC



0.30 mg wire loss

4.8% caliper loss

Test method: Einlehner AT-2000, standard 75 min. test

Figure 8. Abrasion of PCC versus Calcined Kaolin for White Top Linerboard

In addition to gains in brightness and appearance, customers are reporting improved flexographic print quality. The increased sheet porosity resulting from PCC use provides uniform controlled ink receptivity which gives sharp clear print images. The open sheet does however result in slightly higher ink consumption. The predominant feeling is that the print quality improvement outweighs the slight increase in ink usage.

Conclusions:

PCC fillers can and are being used effectively in solid bleached board and white top linerboard grades. The brightness, morphology, and light-scattering characteristics of PCC fillers can significantly improve paperboard properties and provide cost savings to meet the dynamic and changing paperboard market needs.

PCC fillers function by offering paper producers increased brightness, maintaining bulk, increasing sheet porosity, and reducing fiber usage. They benefit the papermaker by increasing brightness, reducing manufacturing cost, and improving printability.

Acknowledgement:

The authors wish to thank the members of the Paperboard Filling Team and all field support personnel for their successful efforts to promote and implement the benefits of PCC filler technology throughout the world.

References:

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