Filler Engineering for Energy Savings and Improved Paper Properties

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Advantages of Using Filler in Paper

• Increase filler content in paper will improve paper optical properties (brightness, opacity, printing quality)
• Increase filler content in paper will reduce the papermaking cost
  – pulp price: $350-600/ton
  – filler cost (clay or PCC): $130-150/ton
• Increase water drainage rate
• Increase solid content of paper web
• Substitution of fiber will reduce the carbon footprint
Problems of Using Filler in Paper

- Reduces the paper strength
- Reduce the bulk
- Some effects on the wet-end operation
  - retention
  - sizing reversion (PCC filler)
  - water clarification
  - two sidedness
  - dense paper
  - Linting and dusting
Filler Engineering: Past Researches

- New generation fillers
  - High aspect ratio fillers (PCC, Clay)
  - Low cost fillers (Gypsum fillers)
  - High quality fillers (TiO$_2$, nanofillers)
  - Nanosilicate fillers

- Filler modification and novel treatment techniques
  - Wood fines-filler composites
  - Pretreatment of fillers (preflocculation)
  - Polymer coating
Our Approach: Filler Treatment Using Starch

In traditional papermaking:
- Starch adsorbed on filler

Our approach:
- Starch coated on filler aggregate

Coated Filler
Filler Modification with Polymer Coating

- Spray drying method
- Wet slurry method
- Polymer precipitation method

The best method depends on your paper grade, location (transportation cost), and fillers (PCC, Clay)
Spray Drying Method

Filler + starch + water

Cook

Filler + dissolved starch + water

Spray Dry

Starch-coated filler

Starch used is raw starch, which is ~$0.3/Lb, comparing with cationic starch of ~$1.3/lb

Both potato and corn starch can be used

2.5% starch based on clay is enough
Modifying the Spraying Dry Method by Adding Crosslinker

One of our engineered fillers: raw starch (corn starch) coated clay: Spray dried method
Starch Coated Clay for Linerboard Application

• Why do we add filler in linerboard?
  – Energy saving
  – Machine running ability improvement
  – Printing quality
  – Raw material cost reduction

• Problems
  – Strength reduction
  – Filler retention
• Modified Clay
  – IMERYS (Atlanta, GA)
  – Modified clay coated with precooked 2.5% corn starch via spray drying of 40% clay slurry
  – Control: conventional clay with 3 lb/ton cationic starch
• Furnish
  – SW kraft pulp, kappa 105, Inland
  – Pulp was beaten to C.S.F. 350 ml
• Handsheets
  – TAPPI method, 180 g/m², CPAM retention aid.

**Tensile Index vs. Filler Content**

**Ring Crush Index vs. Filler Content at Different CPAM Levels**
Handsheat Properties Using different Starches (Lab Results)
Stiffness reduced only slightly at 10% modified clay content. Over 10% increase in tensile and ring crush with modified vs conventional clay
Herty Pilot Trial

**Effect of Clay on Sheet Dewatering**

- **Dryness off Couch**
  - Clay, Couch C
  - Mod. Clay, Couch C
  - Clay, Press C
  - Mod. Clay, Press C

- **Dryness out of Press**
  - Red dots: Clay, Couch C
  - Blue dots: Mod. Clay, Couch C
  - Red triangles: Clay, Press C
  - Blue squares: Mod. Clay, Press C

**Graphs**

- **Bulk (cm³/g)** vs. **Clay content (%)**
  - Modified clay
  - Original clay

- **Sheet Ash Content (%)** vs. **Solid Content (%)**

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**Table**

- **Clay content (%)**
- **Bulk (cm³/g)**
- **Modified clay**
- **Original clay**
Summary of Starch Coated Clay in Linerboard Application (Spray Dry Method)

- Raw Starch can be easily coated on clay surface
- 2.5% starch (based on filler) is enough to achieve highest strength benefit
- Adding starch coated filler to linerboard can reduce papermaking cost
- Up to 8% of starch coated filler do not reduce the strength properties
- Adding filler can significantly improve the drainage rate, solid content and drying rate
- Several mill trials using starch coated filler have been done
Wet methods

Starch-clay Composite by Fatty Acid Complexation

Unmodified corn starch and palmitic acid (or stearic acid sodium salt)

The mechanism of starch-filler composite is due to the formation of starch-fatty acid complex which is water insoluble at low pH.
Starch-Clay Composite Aggregates Formation

Clay slurry (2-25%)

Cooked raw starch

Fatty acid

Low pH < 4

Starch-clay composite suspension
Solubility: temperature and pH effects

Temperature, °C

Solubility
Swelling Power

%

20 40 60 80 100

pH

Solubility
Swelling Power

%
Application of the technique

- Can be used for modifying both clay and PCC. For PCC, calcium ions can precipitate the starch and no acid is needed to bring the pH down.
- Can be applied to different paper grades.
Copy paper

Physical properties

~120% increase comparing to clay-fiber only

~60% increase comparing to cationic starch (conventional method) method
Copy paper

Physical properties (cont.)

- Burst Index, kPa
- Folding Index, times

Graphs showing the effect of composite dosage (%) on Burst Index and Folding Index for different starch and clay compositions.
Copy paper

Optical properties

![Graphs showing Optical properties of copy paper](image-url)
Copy paper

Distribution and Bonding (SEM)

fatty acid 10%

fatty acid 30%

fatty acid 10%

fatty acid 30%
Additional advantage (sizing)

Rate of change of wettability (R) =
Change of contact angle / change of time
The pulp with various amounts of clay-starch composites was diluted to 1L of 0.5 wt% respectively.

Percol-175 was added at 0.1wt% based on solid weight for clay retention.

Drainage time was measured by a Dynamic drainage analyzer (DDA).

Energy saving and machine runnability improvement by adding fillers

Drainage test
Drainage is measured as the time from the start of run until air start being sucked though the sheet.
Effect of filler content on the drainage rate

Clay filler; C-PAM retention aid at 2lb/ton; linerboard

Drainage rate was increased (or drainage time decreased) >20% by adding 20% fillers
Water removal tests (press and drying sections)

- Unbleached kraft pulp (60% hardwood and 40% softwood) was refined in a Valley beater to a freeness of 400 CSF.
- Starch modified clay (spray-dry method) was provided by Imerys as the filler.
- Percol-175 (high molecular weight, low charge density polyacrylamide retention aid) was obtained from Ciba specialty Chemicals.
- The filler content was determined by ashing the paper in a muffler oven according to the standard TAPPI method T211.
- After a slightly wet pressing (50psi, 5min, no heating), handsheets with a target basis weight of 200g/m² were prepared and ready for pressing and drying test.
Wet pressing test

- The testing system used was the MTS Testing Machine controlled by a MTS 458.20 Micro Console.
- Handsheets were cut to a suitable size for the MTS press. The weights of the samples before and after press (600psi) were both measured immediately.
**Drying test**

- After wet pressing test, the sheets were dried at 105°C by a Mettler Toledo® LJ16 moisture analyzer.
- The percent of solids content was measured every 30 seconds, and the lost water weight was obtained.
Effect of filler addition on the solid content after press

Test-1 and Test-2 were two independent tests with the same pressure.
Solid content increased from 30% to 36% under 600 psi pressing.
Solid content increased 6 absolute points by adding 23% filler.
Effect of filler addition on the solid content after press

Relative water content (water/dry paper) after press decreased from 2.3 to 1.65 by adding 25% filler, which corresponds to 26% reduction in the water content.

Two figures were generated from two independent tests.
Web solid content as a function of press cycles at 600psi

Solid content increased by 5 weight percents by adding 23% filler.

For every 1% increase in exiting press solids, an approximate 4% increase in machine speed can be projected on a dryer-limited machine. 5% increase in solid content will result in 20% improvement in the machine speed.
Solid content as a function of filler content

Different pressure (single cycle)

Different cycles at 600 psi
Effect of filler addition on the drying rate

The water drying time decreased from 10 minutes to 8 minutes, which saving drying energy by 20%.

Two figures were generated from two independent tests:

Drying time (8min) with 24% filler
Drying time (10min) with 0% filler

The water drying time decreased from 10 minutes to 8 minutes, which saving drying energy by 20%.
Mill Trials

- 5 mill trials have been done by Imerys at different mills (4 at Interstate Paper and 1 at Stora Enso).
- Linerboard and starch coated filler made by spray drying was used.
Impact of Traditional Filler in Linerboard

Most suitable for mills making heavy weight linerboard with some strength to give. Probably not applicable across the grade range for any mill. Probably won’t allow incremental production gains (machine speed gains not possible due to strength loss)

- improved drying rates recouped as energy savings, or if machine can refine more will gain back some strength whilst reducing CSF
Commercial Trial History

- March 2007: 8 hour trial on 55lb (268 g/m²) High Performance Liner
  - Speed kept constant
  - 10% reduction in steam demand seen at 4% in base ply
- October 2007: 24 hour trial on same grade as previous
  - Machine speed gains of 10-13 m/min were achieved
  - Old Corrugated Containerboard (OCC/recycled) flow was interrupted, which allowed an unexpected evaluation of OCC versus SEK
  - SEK appeared to have more impact on machine speed at lower levels than OCC
- March 2008: 72 hour trial encompassing a range of grades
  - Addition rates up to 5.5% were run successfully
  - Significant gains in productivity (up to 6%) were achieved relative to typical run rates (speed increases >30 m/min on some grades)

**In all trials:**
- No paper was lost to breaks
- Strength levels were within specification
- Runnability was excellent

**Interstate Paper was member of a state funded project, and is aware that this information has been shared with other paperboard producers.**
### Commercial Trial 3: Productivity Summary

<table>
<thead>
<tr>
<th>Grade</th>
<th>42# Mullen (205g/m² Standard)</th>
<th>69# Mullen (336g/m² Standard)</th>
<th>55# STFI (268g/m² High Performance)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average SEK addition</strong></td>
<td>3.90%</td>
<td>4.50%</td>
<td>4.80%</td>
</tr>
<tr>
<td>Target Speed (m/min)</td>
<td>750</td>
<td>506</td>
<td>584</td>
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<tr>
<td>Trial Speed (m/min)</td>
<td>774</td>
<td>522</td>
<td>601</td>
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<tr>
<td>Target Production Rate (stph)</td>
<td>43.9</td>
<td>48.7</td>
<td>44.8</td>
</tr>
<tr>
<td>Trial Production Rate (stph)</td>
<td>45.3</td>
<td>50.3</td>
<td>46.1</td>
</tr>
<tr>
<td>Max Speed (m/min)</td>
<td>779</td>
<td>534</td>
<td>618</td>
</tr>
<tr>
<td>Max Trial Production Rate (stph)</td>
<td>45.6</td>
<td>51.3</td>
<td>47.4</td>
</tr>
</tbody>
</table>
Commercial Trial 3: Impact on Strength

No correlation between critical strength tests and SEK dosage rates.
Value Proposition for SEK in Linerboard

4 -5% SEK in linerboard results in the following benefits:

• Fiber replacement or extender
• Can substitute or extend OCC and Virgin fiber
• No statistical impact on strength and slide angle
• Faster drainage and drying
• Reduced steam demand - 10%
• Potential for speed increase - ~ 100 fpm
• Production rate increase of up to 3tph on 55lb liner
Overall Conclusions

- Adding our starch coated clay to linerboards
  - improve water drainage rate
  - increase machine runnability
  - increase solid content by 3-5 absolute point
  - Saving drying energy by >10%
- Starch coated filler does not detrimentally impact linerboard sheet strength up to filler content of 8%
- The starch modified filler can also be used to improve newsprint properties
- The starch coated filler shows higher strength properties than adding filler and starch separately in wet end.
- Two modification methods (wet and spray drying) are developed
- Our techniques can be used for both PCC and clay
- Several mill trials have been done, and the longest trial was last three weeks. The trial was very success.
- Intellectual Property
  - A patent of filler modification use starch and starch-fatty acid composite has been filed at US Patent Agent in September 2007
    - Publication number: US 2008/0087396 A1