Energy Saving in Papermaking Through Advanced Filler Engineering

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## Agenda 2020: Aggressive goals for cost reduction

<table>
<thead>
<tr>
<th>R&amp;D Focus Areas</th>
<th>Steam and Electrical Savings</th>
<th>Cost Savings ($/ton)</th>
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<tbody>
<tr>
<td></td>
<td>Million Btu/ton</td>
<td>Trillion Btu/ year</td>
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<tr>
<td>Pulping/ Bleaching</td>
<td>1</td>
<td>80</td>
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<tr>
<td>Black Liquor Concentration</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td>Causticizing</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td>Dewatering/ Drying</td>
<td>2.5</td>
<td>250</td>
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<tr>
<td>Increased Filler/ Sustainable, Cost-Effective Pigments</td>
<td>3.6</td>
<td>75</td>
</tr>
<tr>
<td>Sheet Property Development</td>
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<td>50</td>
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</tbody>
</table>
Our Approach: Filler Treatment Using Starch

In traditional papermaking, starch is adsorbed on filler. Our approach involves starch being coated on filler, forming an aggregate.
Previous Key findings

- **Mill trials**
  - Several mill trials have been done, and the longest trial is 11 days. All trials run very well and no break associated to the trials. The trials show that
  - Starch coated filler does not detrimentally impact linerboard sheet strength up to filler content of 5%
  - Significant gains in productivity (up to 6%) were achieved relative to typical run rates (speed increases >30 m/min on some grades)
  - Reduced ~10% steam demand

- **Laboratory works**
  - The starch coated filler shows higher strength properties than traditional wet end application
  - The fillers can be used for multi-grades of papers
  - Saving drying energy by >10%
  - Two modification methods (wet and spray drying) have been developed
  - Our techniques can be used for both PCC and clay
Objectives

- Develop a modify starch coated clay filler technology for GA SW bleached kraft, linerboard, folding carton, and newsprint.
- Incorporate 5-10% modified filler into newsprint and 10-20% modified filler for copy paper.
- Develop a wet starch-precipitation method for onsite PCC filler modification at paper mills.
- Provide papermakers a predictive relationship between modified filler content and dewatering and drying properties for GA’s newsprint and print grades (Note: The research done in FY09 focused on clay in linerboard and will be extended to other grades in FY10).
Two Methods for Filler Modification with Starch Coating

- Starch coated clay: spray dry method
- Starch coated clay: wet precipitation method
Impact of Traditional Filler in Linerboard Using unmodified Clay Filler

4 mill trials have been done by Imerys at different mills
Linerboard and starch coated filler made by spray drying was used
Accomplishments in FY09-10

• **Filler Modification methods:**
  – Wet Slurry Method for starch coating: Starch-clay Composite with Fatty Acid Precipitation
  – Wet Slurry Method for starch coating: Starch-PCC Composite with Fatty Acid
  – Wet Slurry Method Using CMC Coated PCC

• **Modified filler characterization**
  – Particle size, shear resistance, zeta potential

• **Paper Grades**
  – Linerboard
  – Newsprint
Starch/fatty acid modified clay for linerboard application

Starch-fatty acid form a complex which can be precipitated by lowering pH or adding Ca$^{2+}$

Characterization of Starch Coated Clays by Fatty Acid Precipitation Method

• The properties of the starch-modified fillers are important
  – What are the surface charge?
  – How much starch are coated and how much will dissolve in wet water? Will that are problems?
  – What is the size of precipitated filler-starch aggregates?
  – Does the aggregate size shear sensitive?
## Starch Coating Efficiency

The efficiency of starch coating can be calculated using the formula:

\[
\text{coating efficiency} \, (\%) = \left( \frac{\text{wt. of initial starch} - \text{wt. of dissolved starch}}{\text{wt. of initial starch}} \right) \times 100\%
\]

### Conditions

<table>
<thead>
<tr>
<th>No.</th>
<th>Conditions</th>
<th>Starch concentration in the water (ppm)</th>
<th>Coating efficiency (%)</th>
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</thead>
<tbody>
<tr>
<td>1#</td>
<td>starch:filler=1:4, fatty acid=5%</td>
<td>61.86</td>
<td>98.02</td>
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<tr>
<td>2#</td>
<td>starch:filler=1:4, fatty acid=10%</td>
<td>59.70</td>
<td>98.09</td>
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<td>3#</td>
<td>starch:filler=1:4, fatty acid=15%</td>
<td>58.89</td>
<td>98.12</td>
</tr>
<tr>
<td>4#</td>
<td>starch:filler=1:4, fatty acid=20%</td>
<td>57.16</td>
<td>98.17</td>
</tr>
<tr>
<td>5#</td>
<td>starch:filler=1:8, fatty acid=10%</td>
<td>57.71</td>
<td>98.15</td>
</tr>
</tbody>
</table>

Note: The starch dosage is 3.125g, the filler dosage is 4 times or 8 times of starch.

**Conclusion:** At various conditions, >98% of starch will be coated on filler surface.
Zeta potential of starch-fatty acid coated clay increases as the fatty acid concentration increases. The low zeta potential can improve the retention of fillers on fiber surface

Reason: the negative charges on clay surface are shield by coated starch layer.
Particle sizes of the aggregates of starch modified clay under shear

The aggregate size is between 23-33 micrometers.

It decreases with the shear time, but the decrease is not significant, suggesting the starch-fatty acid complex on the clay surface is strong.

Agitation speed: 1000 rpm
Starch-fatty acid modified fillers for improving linerboard properties

- Previous works, including mill trials, are based on the filler made from spray drying method.
- Starch-fatty acid precipitation method can be applied to paper mills without significantly change their facilities.
Starch-fatty acid modified fillers for improving linerboard properties

Pulp Furnish: Old corrugated container
Clay: Kaolin Clay (provided by Imerys)
Raw Starch: B200 (Corn starch, Grain process)
Cationic starch (added in wet end, for comparison)
Fatty acid: Palmitic acid
Cationic retention aid: Percol-175
Handsheets basis weight: 180g/m²
Linerboard (from OCC) properties

1.5
2
2.5
3
3.5
4
Bursting index (kPa\cdot m^2/g)

0
3
6
9
12
Filler content/%

Bursting index vs Filler content

10
20
30
40
50
Tensile index (N\cdot m/g)

0
3
6
9
12
Filler content/%

Tensile index vs Filler content

Modified clay 1:4 means 1 part of starch with 4 parts of clay
Cationic starch addition: 6 lb/ton
Linerboard (from OCC) properties

Modified clay 1:4 means 1 part of starch with 4 parts of clay
Cationic starch addition: 6 lb/ton
Newsprint (wet method): Effects of Different Starch Addition Methods on Physical Properties

0.1P-1S-3F donates:
- 0.05 part of palmitic acid,
- 1 part of starch
- 3 parts of filler

0.1P-1S-3F donates:
- 0.1 part of palmitic acid,
- 1 parts of starch
- 3 parts of filler
Effects of Different Starch Addition Methods on Physical Properties

![Graphs showing effects of different starch addition methods on ZDT and Folding properties.](chart)
Effects of the Fatty Acid on Physical Properties

![Graph showing the effects of fatty acid on physical properties. The graph plots bulk vs. filler percentage, with different markers for different fatty acid concentrations.](image-url)
One concern of using fatty acid in paper is the reduction of the friction of the paper sheets.

The handsheet was adhered on the surface of aluminum alloy plate and put a 2 grams stainless balance weight on the top of handsheet. Slowly raise the aluminum plate up till the weight started to move. Record the angle that weight starts to move as the measured friction. The less friction force of paper, the smaller angle the weight starts to move.
Conclusions for starch-fatty acid coated fillers

- Starch-Palmitic Acid-Clay composite is easy to make in mill.
- The sheet properties of newsprints and linerboard from OCC can be improved.
- Coated starch on filler surface is better than directly adding cationic starch to the wet end.
- There is no significant decrease in friction when filler dosage up to 20% and palmitic acid usage up to 20% of starch.
Linerboard with PCC modified with CMC

- Pulp Furnish: Old corrugated container
- PCC: Albarca HO (Specialty Mineral Inc, USA)
- Cationic starch
- CMC (Aldrich)
- Cationic retention aid: Percol-175
- Handsheet basis weight: 180 g/m²
CMC and CMS Precipitation Mechanism

- CMC is anionically charged water-soluble polymer. When cationically charged polyDADMAC is added, the neutralization reaction will result in water-insoluble polymer complex that can precipitate on filler surface.

![CMC structure and possible reaction between CMC and polyDADMAC](image)
Fibrous PCC Aggregates from CMC Precipitation

300 μm
Linerboard (OCC) made from CMC coated PCC
Linerboard (OCC) made from CMC coated PCC

- **Bursting strength vs Filler content/%**
  - **Original PCC**
  - **CMC + Original PCC**
  - **CMC Modified PCC**

- **Stiffness vs Filler content**
  - **Original PCC**
  - **CMC + Original PCC**
  - **CMC Modified PCC**
Linerboard (OCC) made from CMC coated PCC
Where is the technique standing?

- **Starch-fatty acid precipitation method**
  - A US patent application based on wet slurry method has been filed by Georgia Tech
- **Spray-drying method**
  - It is commercially available
  - Being developed for applications
- **Several companies have been interested the technique**
  - Developing mill specific projects
  - Fillers work reviewed at IPST workshops
Future Works

Developing a consortium on Filler-Reduced Energy Consortium

Looking at Barrier Properties