Starch as a Driver
In Papermaking Development

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**Imerys
Advantages of Using Filler in Paper

- Increased filler content in paper will improve paper optical properties
  - Brightness
  - Opacity
  - Print quality
- Increased filler content in paper will reduce papermaking materials costs
  - Pulp price: $250-400/ton
  - Filler cost (clay or PCC): $100-130/ton
- Increase water drainage, drying rate
Potential Problems of Using Filler in Paper

• Effects on wet and dry end operations
  – Retention
  – Water clarification
  – Dusting

• Effects on sheet properties
  – Sheet two-sidedness
  – Reduced paper strength
  – Reduced bulk
  – Linting
Past Research in Filler Modification

• New filler development
  – Fibril fillers
  – Pretreatment of fillers

• Coating polymer on filler surface
  – Polymers used in the literature are relatively expensive
  – Some polymers can cause environmental problems
  – Effect on paper properties, such as causing unnecessary sizing, increasing recycling difficulty
Objective

Develop new bonding fillers to improve existing sheet properties while decreasing fiber costs
Small fiber-fiber contact area: low paper strength

Large fiber-fiber contact area: high paper strength

Conceptual diagram showing impact of filler/aggregate size on strength
Our Approach: Filler Treatment Using Starch

In traditional papermaking:
- Filler
- Starch adsorbed on filler

Our approach:
- Filler
- Coated Filler
- Starch coated on filler
Approach Using Starch Coating

Filler aggregates coated with starch and with suitable particle size

- Larger particle size: decreased contact area between fiber and filler
- Increased mechanical retention
- Improved bonding (increased bonded area vs. untreated clay)
Filler Treatment with Starch

1. **Filler + starch + water**
   - **Starch cooked** with or without clay

2. **Filler + dissolved starch + water**
   - **Dried** (feed range of 20-50% solids)

3. **Starch-coated filler**

- 2.5 or 5% starch based on clay
- During drying, starch forms network
- Clay is encapsulated with starch molecules

20-40 µm; starch coated
Coated starch relatively water-insoluble
Clay Modification

Clay

Clay with 5% coated cationic starch
Clay Modification

Clay with 5% coated raw potato starch

Clay with 25% coated raw potato starch
Starch Dissolving Profile of 2.5% Starch Modified Clay
(stirring speed 1200 rpm, clay consistency 10g/L)

- 25°C, Corn starch modified clay
- 25°C, potato starch modified clay
- 55°C, corn starch modified clay
- 55°C, potato starch modified clay

Starch dissolving, % (on starch coated on clay)

Stir time, min.
Dried starch absorbs water, swells, deforms
- indication of behavior on clay
  which would enhance bonding
Lab Results

- Starch coated and dried on clay surface can increase paper strength significantly (10-15%) vs. use of unmodified clay
  - Ring crush
  - Similar optical properties
- Different starches (corn, potato, cationic starch) gave similar effects
- Starch amount as little as 2.5% of the filler to give significant positive effect
Lab Results (Continued)

- Confirmed spray-dried starch coated clay has increased paper strength vs. unmodified clay (handsheets)
  - Also bulk and stiffness improvement
  - Modified clay does not reduce clay’s ability to increase paper brightness
- Potential to use low cost clay and low grade starch to produce high strength paper/board with high filler content
Laboratory Results

Handsheet Tensile Strength

Before Calendering

Calendered

Control: 5% starch based on unmodified clay;
i.e., at 10% clay in sheet: 0.5% starch in sheet (10 lb/t)
Ring Crush, Calendered Handsheets

Can add at least 10-15% modified clay and get same ring crush
## Clay Characterization

Clay surface area and particle size

<table>
<thead>
<tr>
<th>Surface area (m²/g)</th>
<th>Clay</th>
<th>2.5% Corn</th>
<th>5% Corn</th>
<th>2.5% Potato</th>
<th>7.5% Potato</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>10.7</td>
<td>7.9</td>
<td>7.0</td>
<td>8.2</td>
<td>8.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Particle size (micron)</th>
<th>Percentage less than given particle size</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>98</td>
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<tr>
<td>5</td>
<td>88</td>
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<tr>
<td>2</td>
<td>56</td>
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<td>1</td>
<td>35</td>
</tr>
<tr>
<td>.5</td>
<td>19</td>
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<td>.25</td>
<td>8</td>
</tr>
<tr>
<td>.2</td>
<td>6</td>
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</table>

Modified clays: lower surface area, larger particle size
Pilot Results

• Modified clay filler produced using pilot spray dryer at IPST, at IMERYS
• Pilot mill trial at Herty Foundation with spray dried clay from Imerys spray dryer
• Confirmed scale-up
  – Sheet properties
  – Dewatering improvement with clay addition
Spray Dryer Evaluation

Clay Viscosity

- Shear viscosity measured for control clay and modified clay
  - To assess potential for spray drying
  - Control: 50% solids unmodified clay
  - Modified clay: 20-50% solids range investigated
Spray Dryer Evaluation

<table>
<thead>
<tr>
<th>Sample</th>
<th>Feed rate (ml/min)</th>
<th>Gas Temp (°C)</th>
<th>Mass yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20% Clay</td>
<td>24.5</td>
<td>210 120</td>
<td>72.0</td>
</tr>
<tr>
<td>20-2.5Corn</td>
<td>22.3</td>
<td>210 120</td>
<td>99.0</td>
</tr>
<tr>
<td>20-5Corn</td>
<td>25.3</td>
<td>210 120</td>
<td>88.1</td>
</tr>
<tr>
<td>20-2.5Potato</td>
<td>35.6</td>
<td>210 120</td>
<td>74.0</td>
</tr>
<tr>
<td>20-5Potato</td>
<td>24.6</td>
<td>210 120</td>
<td>82.1</td>
</tr>
<tr>
<td>50% Clay</td>
<td>27.5</td>
<td>210 120</td>
<td>79.7</td>
</tr>
<tr>
<td>30-2.5Corn</td>
<td>25.3</td>
<td>210 120</td>
<td>96.9</td>
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<tr>
<td>35-2.5Corn</td>
<td>17.3</td>
<td>210 120</td>
<td>95.1</td>
</tr>
<tr>
<td>40-2.5Corn</td>
<td>20.8</td>
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<td>97.8</td>
</tr>
<tr>
<td>45-2.5Corn</td>
<td>7.5</td>
<td>210 120</td>
<td>92.6</td>
</tr>
</tbody>
</table>

- Results: modified clay can be spray dried up to 40-45% clay
Spray – Dried Starch-Coated Clay – Handsheet Trials

• Modified Clay
  – IMERYS (Atlanta, GA)
  – Modified clay coated with precooked 2.5% corn starch via spray drying of 40% clay slurry
  – Particle size (light scattering, in suspension) increased with modified clay vs. conventional clay

• 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.

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![Graph showing Tensile Index vs. Filler Content](image1)

![Graph showing Ring Crush Index vs. Filler Content at Different CPAM Levels](image2)
## Spray-Dried Starch-Coated Clay-Herty Pilot Trial

<table>
<thead>
<tr>
<th></th>
<th>CONTROL (No clay)</th>
<th>ORIGINAL CLAY</th>
<th>STARCH COATED CLAY</th>
</tr>
</thead>
</table>
| **Filler**       | None              | Sstd clay (High AR)  
• 10 %  
• 20 %       | Mod. Clay (1.8% starch; spray dried@20% solids )  
• 10 %  
• 20 %       |
| **Furnish**      | Reslushed liner furnish (IP), mixed SW/HW, CSF 500-550 ml |               |                    |
| **PM**           | Single ply; BW 170 g/m² ; 75 fpm |               |                    |
| **Chemicals**    | Corn starch       | Corn starch (2.5%)  
RA: CPAM (Percol 175) 1 ppm | RA: CPAM       |
|                  |                   |               |                    |

*AR: Clay aspect ratio*
Spray-Dried Starch-Coated Clay - Herty Pilot Trial

Over 10% increase in tensile and ring crush with modified vs. conventional clay
Decrease in strength vs. unfilled control (starch content less than target)
Herty Pilot Trial: Bulk, Stiffness

**Bulk** maintained at 10% modified clay content

**Stiffness** reduced only slightly at 10% modified clay content; stiffness increases with bonding, but is more sensitive to sheet thickness (Moberg)
Similar brightness increase with modified and conventional clay
Effect of Dispersion Time

Long dispersion time had no effect on tensile, but possible effect on ring crush
10% original clay

Consistent with particle size measurements: IPST (laser- orig. clay: 9.5 μm, modified clay: 38.2 μm); Imerys (Sedigaph: mod. clay slightly coarser)
20% unmodified clay

20% modified clay
Effect of Clay on Dewatering

Significant effect of clay or modified clay on dewatering.
Linerboard capacities in USA are close to Kaolin deposits in SE

Source: P Ince, 2001 USDA FPL
Logistics Unique to SE USA Paper Industry
Summary

• Modified filler platform developed
• Potential to use low cost clay and low grade starch to produce high strength paper/board with high filler content
  – Decreased fiber and processing costs
• Evaluating options for modified clay production
  – Lower cost clay sources and processing
  – Process development and scale up of modified filler
  – Support of further pilot filler production and applications testing
Acknowledgement

- Georgia TIP3 Program for financial support
- Imerys