Issues Associated with Testing the Consistency of CMP Filtration Products

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Presentation Outline

- Continuous Improvement (new products, manufacturing and quality)
- Evaluating product consistency (underlying issues)
- Results from ceria slurry testing
- Results from fumed silica testing
- Resolving fumed silica testing issues with a Levitronix pump
- Comparison of recirculation study results with a theoretical filtration model
Development Based upon Slurry Characteristics

Evolution of typical LPC distributions for fumed silica CMP slurries

Filter efficiency and life testing with 12% solids fumed silica CMP slurry

*Improving CoO by developing products for CMP slurries based upon PSD
Fiber Media Development (Next Generation)

Pall is diligently working towards advancing the state of the art with the latest melt blowing and other fiber based technologies to reach the next level of CMP slurry cleanliness.

<table>
<thead>
<tr>
<th>Current cutting-edge product</th>
<th>Next generation prototype</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Efficiency with PSL = 68%</td>
<td>✓ Efficiency with PSL = 99%</td>
</tr>
<tr>
<td>✓ Norm. Mean pore size = X</td>
<td>✓ Norm. Mean pore size = &lt;0.5X</td>
</tr>
<tr>
<td>✓ Removal efficiency with TD = 93%</td>
<td>✓ Removal efficiency with TD = 99.5%</td>
</tr>
<tr>
<td>✓ Defectivity = X</td>
<td>✓ Defectivity = &lt;0.7X</td>
</tr>
</tbody>
</table>
Development Based upon Quality Methodology (Improving Product Consistency)

Typical manufacturing data for a legacy CMP product

Manufacturing data for a recently developed CMP product
Potential Testing Issues (Product Consistency)

- **Measurement Uncertainties**
  - particle counting
  - flow rates
  - differential pressures

- **Pumps**
  - rotary peristaltic vs. magnetic levitation
Results From Ceria Testing with 0.2μm Depth Filtration

Testing with ceria slurry

<table>
<thead>
<tr>
<th>Filter</th>
<th>Influent</th>
<th>one turnover</th>
<th>15 turnovers</th>
<th>30 turnovers</th>
<th>50 turnovers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lot 1, #1</td>
<td>21690114</td>
<td>16502394</td>
<td>15472282</td>
<td>14650380</td>
<td>14729365</td>
</tr>
<tr>
<td>Lot 1, #2</td>
<td>21557302</td>
<td>16741284</td>
<td>15633184</td>
<td>14802469</td>
<td>14155427</td>
</tr>
<tr>
<td>Lot 2, #1</td>
<td>21309462</td>
<td>16821803</td>
<td>15976357</td>
<td>15173512</td>
<td>13330771</td>
</tr>
<tr>
<td>Lot 2, #2</td>
<td>22397316</td>
<td>17961740</td>
<td>15137691</td>
<td>15131482</td>
<td>14634858</td>
</tr>
<tr>
<td>average</td>
<td>21741049</td>
<td>17008807</td>
<td>15554671</td>
<td>14665961</td>
<td>14212553</td>
</tr>
<tr>
<td>% (Std. deviation)</td>
<td>21%</td>
<td>38%</td>
<td>22%</td>
<td>23%</td>
<td>4.5%</td>
</tr>
</tbody>
</table>
Initial Silica Testing Results with 4.5μm Depth Filtration

### Testing with fumed silica slurry

<table>
<thead>
<tr>
<th>Filter</th>
<th>Lot 1 #1</th>
<th>Lot 1 #2</th>
<th>Lot 2 #1</th>
<th>Lot 2 #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Influent</td>
<td>42548</td>
<td>41450</td>
<td>39010</td>
<td>45521</td>
</tr>
<tr>
<td>one turnover</td>
<td>46799</td>
<td>48747</td>
<td>47163</td>
<td>50328</td>
</tr>
<tr>
<td>15 turnovers</td>
<td>29519</td>
<td>24455</td>
<td>33299</td>
<td>46139</td>
</tr>
<tr>
<td>30 turnovers</td>
<td>72925</td>
<td>50474</td>
<td>57515</td>
<td>89377</td>
</tr>
<tr>
<td>50 turnovers</td>
<td>121925</td>
<td>161604</td>
<td>164767</td>
<td>207469</td>
</tr>
</tbody>
</table>

### Average

- **Influent**: 42132
- **one turnover**: 48384
- **15 turnovers**: 33103
- **30 turnovers**: 67415
- **50 turnovers**: 163941

### % (Std. deviation)

- **Influent**: 6.4%
- **one turnover**: 3.8%
- **15 turnovers**: 32.4%
- **30 turnovers**: 25.6%
- **50 turnovers**: 21.3%
Observations from Ceria and Silica Testing

• Measurement Uncertainties (not an issue)
  - influent particle counts showed deviations from the mean (standard deviation as a percentage of average count) of 2% for ceria and 6% for silica

• Ceria performed as would be expected

• LPC’s for fumed silica increased during testing
  - may be shear induced agglomeration
  - confirm hypothesis using new pump (Levitronix)
Test Results: Rotary Peristaltic vs. Levitronix Pumps

* LPC’s increased 2.5X over a period of 3 hours (45 turnovers) when using the rotary peristaltic pump. There was no appreciable change in LPC’s using the Levitronix pump under the same conditions.
Silica Test Results using Levitonix Pump

Results for > 0.53μm

Results for > 1.01μm

Fumed Silica slurry testing with Levitonix Pump

Particle Counts (>0.53μm)

Lot 1   #1 Lot 1   #2 Lot 2   #1 Lot 2   #2 Filter

Influent one turnover 15 turnovers 30 turnovers 50 turnovers

Fumed Silica slurry testing with Levitonix Pump

Particle Counts (>1.01μm)

Lot 1   #1 Lot 1   #2 Lot 2   #1 Lot 2   #2 Filter

Influent one turnover 15 turnovers 30 turnovers 50 turnovers
Particle Removal in a Recirculating System
(A Theoretical Model)

A theoretical analysis yields the equation: \( C_t = C_0 e^{K(Qt/V)r} \)

where:
- \( C_t \) = concentration of particles at time \( t \)
- \( C_0 \) = concentration of particles at the start of the test
- \( Q \) = recirculation flow rate
- \( V \) = volume of the system
- \( r \) = a constant that is defined as the mixing efficiency (with a range between 0 and 1 with 0 corresponding to no mixing and 1 perfect mixing)
- \( K \) = a constant that incorporates the remaining contributing factors. One of these is the filter’s geometry (including pore size)

The above equation was derived from the differential equation that describes the particulate removal process in the system: \( dC(t) = (KQ/V) C(t)dt \)
Particle Removal in a Recirculating System (Results)

\[ C_t = C_0 e^{K(Qt/v)r} \]

Ceria Slurry using 0.2μm Depth Filter

Fumed Silica Slurry using 4.5μm Depth Filter

*The mixing efficiency component (r) in both examples are nearly the same*
Summary

• Filtration companies are being driven to continuously improve CoO and product consistency
• Pall is accomplishing this through the development of new products (improve CoO) and the incorporation of advanced manufacturing and quality techniques (improve product consistency)
• Evaluating product consistency is not a trivial matter (equipment)
• Ceria slurry did not seem sensitive to pump type; agglomeration occurred for silica slurry when using a rotary peristaltic pump
• Results with both slurries showed Pall products performed in a manner that was within expectations
• LPC results (for both slurries) correlated to a theoretical model designed to determine particle removal in recirculating systems