WEB TENSION IN AN ACCUMULATOR AND INDUSTRY NEEDS FOR THE FUTURE

June 9, 2009

Neal Michal
Technical Leader

Kimberly-Clark Corporation
OVERVIEW

- Definition
- Design
- Challenges
- Experimental Setup
- Tension Plots

- Steady State
- Accumulator Fill
- Accumulator Feed
- Current Research
- Top Ten Research Needs
- Acknowledgments
WHAT IS AN ACCUMULATOR?

- Web storage device
- Allows different velocities
  - Winders / Unwinds
- Lower fixed rollers
- Moving carriage
- Loading by various means
  - Air / hydraulic / servos
- Span tensions
  - Steady state
  - Fill & Feed
ACCUMULATOR DESIGN

- Timing & Storage Calculations
- Most designs are incremental improvements
- Many designs are available: which is best?
PROCESS CHALLENGES

• Wrinkles are the #1 issue
  • Web camber, baggy lanes, floppy edges
  • Seasonal & storage time

• Poor tension control
  • Flutter, weave, fold-over and complete collapse
  • Neckdown, expansion wrinkles and web breaks

• Top waste and delay in converting processes
ACCUMULATOR - COLLAPSED
<table>
<thead>
<tr>
<th><strong>Accumulator Info</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Rollers</td>
<td>17</td>
</tr>
<tr>
<td>Fixed Rollers</td>
<td>9</td>
</tr>
<tr>
<td># Carriage Rollers</td>
<td>8</td>
</tr>
<tr>
<td># Web Spans</td>
<td>16</td>
</tr>
<tr>
<td>Roller Diameter</td>
<td>165.1 mm</td>
</tr>
<tr>
<td>Roller Mass</td>
<td>7.28 kg</td>
</tr>
<tr>
<td>Roller Length</td>
<td>3.6 m</td>
</tr>
<tr>
<td>Roller Inertia</td>
<td>43603 kg(\cdot)mm(^2)</td>
</tr>
<tr>
<td>Accumulator Stroke</td>
<td>5.1 m</td>
</tr>
<tr>
<td>Total Accumulation</td>
<td>81.6 m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Spindle Drive Info</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Base Speed</td>
<td>1,765 rev/min</td>
</tr>
<tr>
<td>Gear Ratio</td>
<td>11.375:1</td>
</tr>
<tr>
<td>Operating Parameters</td>
<td></td>
</tr>
<tr>
<td>------------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Machine Speed</td>
<td>259 m/min</td>
</tr>
<tr>
<td>Deceleration Rate</td>
<td>91.4 m/min/sec</td>
</tr>
<tr>
<td>Acceleration Rate</td>
<td>91.4 m/min/sec</td>
</tr>
<tr>
<td>Stop Time</td>
<td>2.7 sec</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material Info</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Web Material</td>
<td>Polypropylene Spunbond</td>
</tr>
<tr>
<td>Young's Modulus</td>
<td>55 MPa @ 1% Strain</td>
</tr>
<tr>
<td>Basis Weight</td>
<td>13.6 g / m²</td>
</tr>
<tr>
<td>Web Width</td>
<td>3162 mm</td>
</tr>
<tr>
<td>Material Caliper</td>
<td>0.1016 mm</td>
</tr>
<tr>
<td>Poisson's Ratio</td>
<td>3 @ 1% Strain</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Load Cell Info</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer</td>
<td>ABB</td>
</tr>
<tr>
<td>Model #</td>
<td>PFTL301E</td>
</tr>
<tr>
<td>Calibration</td>
<td>400 N</td>
</tr>
</tbody>
</table>
TENSION TREND PLOT
AVERAGED DATA

- Accumulator Entry Tension [%]
- Accumulator Exit Tension [%]
- Accumulator Height [%]
- Spindle B [RPM]
- Spindle A [RPM]
THREE PHASES

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description</th>
<th>Time Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steady State</td>
<td></td>
<td>T = 0-20 sec</td>
</tr>
<tr>
<td>Accumulator Fill</td>
<td></td>
<td>T = 20-80 sec</td>
</tr>
<tr>
<td>Accumulator Feed</td>
<td></td>
<td>T = 20-80 sec</td>
</tr>
</tbody>
</table>

![Graph showing three phases of a process](image)
- Carriage height 35%
- Enter Tension: 88N
- Exit Tension: 110N  
  20% higher
  Bearing drag

- How many rollers should be used?
- Misalignment of the carriage?
- Critical length / width ratio to be avoided?
ACCUMULATOR FILL

- Height: 35→94% (+2.6X)
- Accel: 91.4 m/min/sec
- Enter: 88→32N (- 65%)
- Exit: 110N→132N(+20%)
- Exit tension is 4X of entrance tension

- Why does entering tension not return after accel?
- What mechanical design would reduce the tension differential? What control method should be used?
- Should we drive the rollers? If so how?
ACCUMULATOR FEED - RAW DATA
ACCUMULATOR FEED
AVERAGED DATA

- Stop in 2.7 sec
- Enter:
  - $40N \rightarrow 272N$
  - +680%
- Web neckdown
- Expansion wrinkles
- Splice failures

- How do we reduce tension extremes?
- Correlate: Decel rate / Roller mass / Neckdown / Wrinkles?
- When should the rollers be driven? What controls?
Tension

Entrance
40 - 272 - 120 - 32 - 312 - 120 - 88

88N (+232N / - 48N)

Exit
140 - 48 - 140 - 8 - 196 - 112

110N (+86N / -102N)
SUM OF ENTRY & EXIT TENSION

- Start at 198N
- End of fill 168N - 16%
- Spikes to 396N during decel + 235%
- Drops to 144N during accel - 64%

- What about air/web interaction? Span interaction?
- What is the best mechanical & electrical design?
CURRENT RESEARCH

- Several dozen papers on winding, wrinkling and air/web interaction (WHRC, Good, others)
- Focus is on a single roller in an open span
- Only four research papers on accumulators
- Apparently existing papers are not well understood
- Equipment designs do not reflect research
- Most accumulator information is internal, confidential and empirical in nature
“TOP 10” RESEARCH NEEDS

1. Validated computer models are needed
2. Air / web interaction within a accumulator
3. Non-ideal webs in accumulators
4. Multi-span interaction: tension, wrinkles, lateral
5. Misalignment of a moving carriage
6. High speed –vs- traction for a porous web
7. Larger rollers –vs- wrinkles –vs- roller mass
8. Should we drive rollers in the accumulator? How?
9. What is the best general arrangement?
10. How should the accumulator be controlled?
• Bob Coxe for collecting the data
• Steve Pullen for his support to make this presentation
• Charles Morell and Bob Stargel for their financial support
• Dr. Keith Good for the challenge to make the presentation
• Dr. Karl Reid, Dr Prabhakar Pagilla, Dr. John Shelton, Ron Markum and Dr Balaji Kandadai for their help over the years
• Bruce Feiertag for setting me on this course 21 years ago
Questions?

Neal Michal
nmichal@kcc.com
(770) 587-7378

Kimberly-Clark Corporation