Comparing Results of Measuring Water Based Acrylic Coatings on the Wet-End Versus the Dry-End

• Presented by: Greg Brown, Converting Systems Manager
  Process Sensors Corporation, Milford MA USA
Why Are Acrylic Coatings Important?

- The clarity and gloss that acrylics offer increase shelf appeal
- Acrylic coatings and resins feature high gloss, quick setting coverage that retains color and are resistant to weathering and UV fading
- Acrylics feature a low temperature sealing threshold
- Acrylics are typically applied via a water-based carrier solution that is driven off during the dryer unit operation
Acrylic Coating Application

• Acrylics can be measured on the wet end in the Near Infrared (NIR) based upon the 1.94μ O-H water stretch when the liquid/solid ratio is constant for a given recipe
• The same organic acrylic coating can be measured on the dry end based on the 2.34μ H-C stretch
• The choice of where to measure acrylic coatings is based on product, objective and experience
Light Wavelength Frequencies
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Near Infrared Functional Groups

[Graph showing absorbance vs. wavelength with peaks labeled for Water, Ethanol, Benzene, and Acetone]
Coating Application Process

- Methods for applying water-based acrylics vary widely from gravure roll, reverse roll, mayer rod, doctor blade, slot die, disk, spray, dip and other
- Water is the carrier solution for the acrylic
- Essentially a water-based acrylic is applied to a substrate of paper, film, foil, textile or other
- The water is then driven off by a dryer unit depositing the acrylic hydrocarbon onto the substrate
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Typical Coating Line
Dry End vs. Wet End Measurement

• The main difference between wet end and dry end water based acrylic coat weight measurement is that the wet end measurement is based on water absorption and the dry end measurement is based on hydrocarbon absorption.
• Both are established linear measurements based on the simple \( Y = mX + b \); with \( m \) representing the slope or the span setting of the transmitter and \( b \) representing the \( y \)-intercept, zero or offset adjustment.
• Web speed will have no impact on measurement.
Wet End Water Based Considerations

• Substrate moisture prior to coating has little impact if any on measurement. The water molecules in the coating on top of the paper are much stronger absorbers of NIR energy at 1.94µ than the water molecules hidden in the cellulose fibers of the substrate. No significant impact on measurement. Film moisture is generally fixed and has no impact.

• Liquid Solids Ratio is assumed constant for a given product. When different products have a different Liquid Solids Ratio the transmitter will need a separately named and stored calibration channel that can be activated manually or by an HMI, PLC or network automatically.

• Quicker Measurement allows for Quicker Control, less scrap.
Dry End Water Based Considerations

- Dry end measures actual deposition on substrate
- Dry end hydrocarbon measurement has less absorption variation for a given change in coat weight than wet end moisture absorption variation. Higher sensitivity (span) settings likely required for accurate reading
- Film substrate thickness is assumed to be constant for a given product
- Acrylic and film both absorb at the 2.34µ hydrocarbon peak
- Process Control point further down stream
• Oftentimes, the decision is based on the history and background of managers
• Process control engineers with confidence in their liquid solid ratio control will almost always choose wet end measurement for quicker process control
• Managers from a QC background often prefer dry end measurement for actual deposition
• Sometimes these decisions are made according to application engineering, space or personal bias
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Near Infrared Photometers
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Scanning NIR Transmitter for CD Profile
Ease of Calibration

• Calibration is equally easy for both wet and dry end calibrations
• A range of samples reflected by a high standard of deviation (SD) yields the best results for calibration
• While software promises correct calibration parameters, the sensitivity (slope or span) must be zeroed at the target set point or “Sweet Spot” for maximum accuracy
• Accuracy at the set point is important
• When far outside setpoint in alarm condition, exact accuracy is not as important as system is already in alarm condition
Data Generation

- Two NIR transmitters were mounted in the same lane on the web at the wet end and dry end of an acrylic coating operation.
- Coat weight was varied via applicator roll speed and web speed.
- Web speed varied between 300 and 1400 fpm.
- Sample tagging and collection not ideal but functional.
- Local Calibrations instead of Global Calibrations will tighten standard errors.
Dart Board Definitions
**Definitions For Our Discussions**

**Accuracy:** How close measurement is to target. E.g. how close a dart is to the bull’s eye. Accuracy is calculated from the Standard Deviation of Calibration Residual Values (difference between Lab and Calibrated Transmitter Values).

**Precision:** How close the subsequent dart is to initial dart for same conditions (reproducibility/repeatability).

**Standard Error:** Standard deviation of sample distribution for sample population mean or standard error of mean. Think standard deviation and variable depending on sample population.

**Standard Deviation:** How much variation from the average value. Low SD indicates data points close to mean and high SD indicates values spread out over large range of values. A good calibration requires a high SD value.

**Correlation Coefficient:** Linear relationship between two variables, in this case Lab vs. Transmitter thickness or coat weight measurement. All Correlation Coefficients (CC) are expected to be above 0.85 with 0.94 and above optimal. The closer to 1.0, the closer to perfection. Non-linear relationships can also be handled with NIR software technology, though not needed in these applications. Low CC indicates a low performance expectation.
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<table>
<thead>
<tr>
<th></th>
<th>Lab GSM</th>
<th>Wet End GSM</th>
<th>Dry End GSM</th>
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</thead>
<tbody>
<tr>
<td>Paper Coated Liner</td>
<td>3.5</td>
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<td></td>
<td>15.6</td>
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Product B Film (Separate Calibration Model)

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<th>Lab GSM</th>
<th>Wet End GSM</th>
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Correlation Coefficient

<table>
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<th>Dry End</th>
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<tr>
<td>0.999909193</td>
<td>0.999580161</td>
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Standard Error

<table>
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<th>Standard Error</th>
<th>Wet End</th>
<th>Dry End</th>
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<tbody>
<tr>
<td>0.134593926</td>
<td>0.289382304</td>
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Standard Deviation (Higher is better, indicating a wide range of samples from the median).

<table>
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<tr>
<th>Standard Deviation</th>
<th>Wet End</th>
<th>Dry End</th>
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<tbody>
<tr>
<td>9.691145654</td>
<td>9.636981037</td>
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Wet End vs. Dry End vs. Lab GSM
Linear Regression

Acrylic Coat Weight GSM

![Graph showing comparison between Wet End, Dry End, and Lab GSM.]
### Wet End vs. Dry End vs. Lab GSM, Higher

<table>
<thead>
<tr>
<th>Medium to Heavy Coat Weight GSM</th>
<th>Lab GSM</th>
<th>Wet End GSM</th>
<th>Dry End GSM</th>
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<td>76.8</td>
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<tr>
<td>82.3</td>
<td>82.5</td>
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<tr>
<td>85.6</td>
<td>85.2</td>
<td>85.2</td>
<td></td>
</tr>
</tbody>
</table>

- **Correlation Coefficient**
  - Lab GSM: 0.999216641
  - Wet End: 0.997929891

- **Standard Error**
  - Lab GSM: 0.40614385
  - Wet End: 0.660018855

- **Standard Deviation**
  (Higher is better, indicating a wide range of samples from the median)
  - Lab GSM: 9.298361351
  - Wet End: 9.180751085
Wet End vs. Dry End vs. Lab, Higher GSM
Linear Regression
Global vs. Local Calibrations

- A Global Calibration is one that covers multiple products with a single calibration model.
- A Local Calibration is one that has separate calibration models for each product.
- Global and Local Calibrations will both yield high correlation coefficients over wide ranges.
- Local Calibrations require additional samples for calibration and will yield tighter standard errors.
- For purposes of the data discussed above, Global Calibrations were used to minimize scrap when comparing wet end vs. dry end acrylic coat weight measurements and to provide data throughout the range.
### Global vs. Local Calibrations

<table>
<thead>
<tr>
<th>Film Thickness</th>
<th>MCT PSA Accuracy Local Model (+/-) GSM</th>
<th>MCT PSA Accuracy Global Model (+/-) GSM</th>
<th>MCT PSA Standard Error Local Model (+/-) GSM</th>
<th>MCT PSA Standard Error Global Model (+/-) GSM</th>
<th>Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 mils</td>
<td>0.1</td>
<td>0.3</td>
<td>0.05</td>
<td>0.05</td>
<td>0.99</td>
</tr>
<tr>
<td>35 mils</td>
<td>0.1</td>
<td>0.6</td>
<td>0.1</td>
<td>0.2</td>
<td>0.99</td>
</tr>
<tr>
<td>55 mils</td>
<td>0.1</td>
<td>0.4</td>
<td>0.1</td>
<td>0.4</td>
<td>0.99</td>
</tr>
<tr>
<td>All</td>
<td>1.0</td>
<td></td>
<td>0.43</td>
<td></td>
<td>0.99</td>
</tr>
</tbody>
</table>
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Global vs. Local Calibrations

**Graph I: Lab vs. MCT Coat Weight**
GSM
25 mils PE Substrate
Local Calibration

**Graph II: Lab vs. MCT Coat Weight**
GSM
25 mils PE Substrate
Global Calibration
Global vs. Local Calibrations

Graph III: Lab vs. MCT Coat Weight
GSM
35 mils PE Substrate
Local Calibration

Graph IV: Lab vs. MCT Coat Weight
GSM
35 mils PE Substrate
Global Calibration
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Global vs. Local Calibrations

Graph V: Lab vs. MCT Coat Weight GSM
55 mils PE Substrate
Local Calibration

Graph VI: Lab vs. MCT PSA Coat Weight GSM
55 mils PE Substrate
Global Calibration
Global vs. Local Calibrations

Graph VII: Organic Coating Global Calibration Trend Plot Data
Lab Vs. MCT PSA Coat Weight in GSM Across PE Film Substrate Thickness Changes
Global vs. Local Calibrations

Graph VIII: Data Comparison of Global Versus Local Calibrations

GSM
Conclusions

• Water based Acrylic coatings can be successfully measured on both the wet and dry end for process control and data archiving
• The substrate being coated and the range of coating can both contribute to the application performance
• Different substrates require separate calibrations for individual products
• Water is a stronger absorber of Near IR Energy than Hydrocarbons
• Acrylic and Film both absorb at the measure hydrocarbon peak, 2.34µ
• Film applications generally require a reflector on the opposite side of the web
• With good liquids solids ratio control, wet end measurement is very attractive
• Correlations and standard errors for wet end and dry end measurements are very similar
• Space limitations will often determine best installation location
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Greg Brown
Converting Systems Manager
508.446-4754
gbrown@processsensors.com
gregbrwn9@gmail.com
561.632-5046