Welcome...

Please remember that this session is to be held in strict compliance with the TAPPI Antitrust Policy.

Specifically, discussing prices or pricing policy and discussing any restraint on competition of any kind will not be tolerated.
TAPPI Extrusion Coating
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On-Line Gauging for Extrusion Coating

Session Objectives:

• Understand the need for on-line “real-time” measurement and control
• Define benefits associated with on-line gauging
• Understand the technologies available for on-line gauging
• Understand the measurement methods
Market Needs/Demands

- High Quality Films and Coated Products
- Increased Product Functionality
- New Product Development
- “Just in Time” (JIT) Production
- Proof of Compliance
- Low Cost
Producer Challenges

- Increased Functionality = more layers, thinner layers = more complex structures
- Cost of Materials
- JIT = Shorter Production Runs
- New Product Development
- Process Analysis & Trouble Shooting

Cannot be accomplished w/periodic lab sampling
The Role for On-line Gauging

- Continuous Real Time Measurement
- Repeatability of Measurement
- Process Control
- Reporting Capability
- Data Collection
- Process Diagnostic Tool
Gauging Results

Results of Continuous On-line Measurement and Control

Target

±5%

±10%
Variation Definitions

- **Short Term Machine Direction (STMD)**
  - Cyclic, one minute period or less
    - Surges, roll runout, air knife air flow 

- **Long Term Machine Direction (LTMD)**
  - Cyclic, minutes to hours, days
    - Feed variation, temps cycling, shift changes

- **Profile (PRO)**
  - Cross machine
    - Die bolt, air knife/blade, nip pressure
Gauging Impact on Process Variation

- **STMD**
  - Display, analysis, indirect control

- **LTMD**
  - Display and direct control

- **PRO**
  - Display and direct control
Gauging Sensor Technologies

• **Isotope**
  – Beta Transmission
  – Gamma Backscatter

• **Infrared Absorption (NIR)**
  – IR Backscatter

• **X-ray**
  – XRT (x-ray transmission)
Beta Transmission Sensor

- Mass measurement (wt/area)
- Range to 5500 gsm (215mils)
- Some sensitivity to composition, presence of mineral / metal additives
- Dual-sided measurement
- Periodic standardization
- Typical precision: +/-0.25%
- Streak resolution 1mm
Beta Transmission Theory

- Transmission Theory
  - Beta Particles are emitted from source
  - Beta Particles are attenuated by material
  - Detector converts Beta Particles to electrical signal
  - Signal is proportional to mass
Beta Sources

- Promethium
  - Thin Coatings/Films (0-200g/m2)
- Krypton
  - Coatings/Film/Sheet (25-1200 g/m2)
- Strontium
  - Sheet (100-5500 g/m2)
Beta transmission Sensor & Scanner
Gamma Backscatter Sensor

- Mass Measurement (wt/area)
- Range - 25-25000 g/m2 (1-1000 mils)
- Typical precision +/-0.5%
- Low Composition Sensitivity
- Single-Sided Sensor
- No Standardization
- Small Size
Gamma Backscatter Theory

- Theory of Operation
  - Photons emitted from source
  - Photons strike product and some scatter back
  - Scintillation Crystal converts photons to light
  - Photomultiplier Tube amplifies light and converts to pulses
  - Pulse rate is proportional to mass
GBS Sensor and Scanner
Infrared Backscatter Sensor

- Selective absorption mass measurement
- Direct measurement of coatings on substrate
- Measurement range 0-1000 g/m²
- Precision +/- 0.1 %
- Passline Tolerance (±50mm)
- No Standardization Required
- Non-isotope
Electromagnetic Spectrum

Near Infra Red
1.0-2.5 microns

Mid Infrared
2.5-10 microns

Increasing Energy
Infrared Absorption

Infrared light is preferentially absorbed by bonds between atoms in a molecule -------

\[ \text{H} \quad \text{O} \quad \text{H} \]

when the energy (wavelength) is **just right**
Near-Infrared Spectrum of Water

Selective absorption at specific wavelengths

%Transmission

Wavelength (micrometers)

1.45µ x 1
1.94µ x 3
2.95µ x 30
Near-Infrared Spectrum of an Organic

Spectrum of polyethylene

Wavelength (micrometers)

% Transmission

1.72 µ X 1
2.32 µ X 3
3.40 µ X 25
The Power of IR Discrimination

Application example:
Thin water based coating on PE
Infrared Sensor Theory

- **IR Absorption**
  - Infrared energy is generated by the lamp
  - Energy is collected and sent through a Filter Wheel
  - Filter Wheel removes unwanted Energy
  - Energy is reflected onto Web
  - Backscattered Energy is Read and Compared to Reference Signal
  - Energy Absorbed is Proportional to Thickness
X-Ray Transmission (XRT)

- Mass Measurement (weight/area)
- Range 0-8000 g/m² (0.2-315 mils)
- Precision 0.10%
- Excellent Streak Resolution
- Some sensitivity to composition, presence of mineral / metal additives
- Few if any Licensing Issues
X-ray Transmission Theory

- **Theory of Operation**
  - X-ray Tube emits X-Ray Energy
  - Some X-rays pass through material
  - Detector converts X-rays into an electrical signal
  - The Electrical Signal is proportional to the Mass
XRT Offers Several Advantages over Nucleonic Gauges

- Excellent Streak Resolution
- Higher Precision, Lower Noise
- Reduced Web Flutter Sensitivity
- Constant Output Over Time
- In Coating Applications, Gauge Readouts Can Be Easily Matched
  - Important for Improved True Net Coat
- With Power removed, no radiation
XRT Sensor Profile Detail Vs Beta

Magnification of ½” strip coating between ½” uncoated areas
Coat Weight Measurement Methods

- **Direct Measurement**
  - Greater Accuracy
  - Simpler System Configuration
  - Lower Cost
  - Requires “selective” sensor (IR)

- **Differential Measurement**
  - More flexible (handles wide array of substrates and coatings)
  - Sensor choices
Direct (IR) Measurement of Coat Weight

- Direct, selective approach requires only one gauge after the coating station
  - Less expensive
  - More accurate
  - Potential to measure coating + moisture
  - Potential to measure coextrusion coating components
Where Direct IR Measurement is not Possible

• IR technique does have limitations:
  – Cannot measure through opaque materials
  – Materials might be similar in composition (same IR signature) not allowing for selective measurement

• In these situations, a differential measurement may be the only solution
Differential Coating Measurement

Coat1 = beta2 – beta1

Coat2 = beta3 – beta2
Accuracy with Differential Approach

Coat Weight Accuracy is Function of **TOTAL** Mass

\[
Error_{coat} = \sqrt{Error_{base}^2 + Error_{gross}^2}
\]

**Note:** differential technique is most accurate when coat weight is a significant percentage of total weight
Example(s) using differential beta gauges with 0.25% accuracy:

- Base substrate = 100 gsm
- Coating = 3 gsm (10 gsm)
- Coat error = SQRT (Base error^2 + Total error^2)
- Coat error = SQRT ((100*.0025)^2 + (103*.0025)^2)
- Coat error = SQRT (0.0625 + 0.0663)
- Coat weight error = 0.36 gsm (.37 gsm)
- Coat weight error = 12% of 3 gsm (3.7% of 10 gsm)

RULE OF THUMB: Coating weight must be at least 10% of total weight (substrate +coating) to achieve acceptable accuracy for Beta sensors and 3% for XRT
Other Challenges for the Differential Technique

• Substrate has variation, both CD and MD
  – Need to prevent this variability from creating coat weight measurement errors via Same Spot scanner synchronization…

• Composition effect
  – Coating and substrate can have different gauge absorption characteristics, using a technique called True Net Coat can eliminate this effect…
Same Spot – Why it’s Important

- The sensor measuring the substrate sees this:

Typical Substrate Variation (+/-5%)
Same Spot – Why it’s Important

- If the coating is a perfectly flat 10 GSM, the coating on the substrate looks like this to the total gauge:
Making a Good Same Spot Measurement

- The total gauge measures the same spot on the web after coating that the substrate sensor measured before coating.
The Result of a Good Same Spot Measurement

• The Coating Profile with Good Same Spot looks like this:

“PERFECT” 10 GSM COATING ON VARIABLE SUBSTRATE
The Result Without Good Same Spot Measurement

- The Resultant Coating Profile With Poor or No Same Spot:
True Net Coat Calibration- Why it’s Important

- Traditional “Gross – Base” technique makes sense mathematically but, some coatings and substrates may be “SEEN” differently by the sensors:
  - Not Particularly True of Gamma Backscatter Which is Mostly Composition Insensitive
  - Beta and X-ray Measurements have Composition Sensitivity
    - Likely that the substrate and coating will have slightly different absorption per unit mass
- Avoids calibrations for each combination of substrate and coating
Calibration – Without True Net Coat

• Typical Application
  – 3 Substrate Types
    • 4 Product Weights per Type
  – 4 Coating Types
    • 3 Coating Weights per Type
  – 12 Coatings on 12 Substrates
  – POTENTIALLY 144 CALIBRATIONS
True Net Coat Approach Eliminates Base Composition Effects

- Match the readouts of the two sensors so that they respond exactly to the same sample sets

- Linearize and calibrate both the base and the gross gauge using the COATING material response curve
  - Since we have same spot measurement and two gauges that respond exactly the same, the base material contributes predictably to the signal magnitude of both the base and gross sensors
Traditional vs. True Net Coat approach

- Traditional approach uses “Gross” curve to calculate Gross weight. Gross curve is in flux, changing as base to coat ratio changes.
- With TNC, to calculate coat, both Gross and Base gauges are calibrated against coat response curve.
Calibration – With True Net Coat

Results in One Calibration for each Coating Type

• Typical Application
  – 3 Substrate Types
    • 4 Product Weights per Type
  – 4 Coating Types
    • 3 Coating Weights per Type

• 4 Calibrations Needed for Measuring Coating Weight Vs a possible 144!
Coating Control

• Auto Profile Control (APC) - PRO
  – Uses auto die with individual die bolt heaters

• Average weight control - LTMD
  – Typically uses screw speed to maintain target coat weight
Analysis/Diagnostic Tools

- Gauge Display Data (on screen or hard copy)
- SPC
- FFT (fast fourier transform) - STMD
- Streak Detection
- OPC for Off-Line Analysis
Summary

• When possible, Infrared Backscatter usually offers the best accuracy at lowest cost for many coating applications (direct measurement)

• If a differential system is required, XRT offers significant performance advantages as compared to Nucleonic gauges
Thanks for your Attention!

Questions

WANTED!