ADVANCES IN ON-LINE MEASUREMENT AND CONTROL FOR OPTIMIZING COATING AND CONVERTING APPLICATIONS

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NDC Technologies Ltd.
Agenda

- NDC Technologies – introduction
- Coating and Lamination Applications
- Measurement options – differential and direct measurement
- Non-contact length and speed measurement
- Conclusions
NDC Technologies Overview

**NDC Systems**
Irwindale CA
- Founded in 1966
- Specialists in online measurement and control systems for web products
- Unrivalled range of measurements & applications solutions

**NDC Sensors**
Maldon UK
- Founded in 1970
- Specialists in on-line infrared measurement systems for web, food, powder, timber and tobacco industries

**NDC Metals**
Alleur Belgium
- Founded in 1950
- Specialists in on-line measurement systems for metals
- X-ray, laser and optical measurements

**BLM**
Dayton OH
- Founded in 1965
- Specialists in on-line measurement systems in metals, cables and tubing
- Laser and ultrasonic-based measurement

- NDC Infrared Engineering formed in 1998
- IRM acquired in 2011, BLM integration 2014
- Direct offices in France, Germany, Italy, India, Singapore, China, Japan
NDC Business Areas

Web Solutions
- Web Gauging Systems

Metals
- Metals Gauging Systems

Sensors
- Analytical and Process Instrumentation

Laser & Ultrasonics
- Cable, Wire & Tube

Measurement Technology:
- NIR Backscatter, Transmission, Reflection – Gamma Backscatter
- Beta Transmission – X-Ray Backscatter, Transmission & Fluorescence
- Microwave – UV Fluorescence – Laser – Ultrasonic
Extrusion, Textile Coating & Laminating Applications

### Flexible Packaging
- Packaging laminates
- Pouches
- Labels
- Multi-wall bags

### Coated / Laminated Papers
- Industrial grade papers
- Release liners
- Adhesive tapes & labels
- Photographic papers
- Crystal & powder packaging
- Bleached board
- Food packaging
  - Liquid packaging
  - Cup stock

### Coated Textile & Nonwovens
- High performance technical fabrics
- Geotextiles
- Medical applications
- Construction
- Many more………

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# Web Solutions: Requirements & Benefits

<table>
<thead>
<tr>
<th>Customer Requirements</th>
<th>Benefits</th>
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<tbody>
<tr>
<td>Quality Compliance</td>
<td><img src="image" alt="Uniform MD &amp; CD coat weight" /></td>
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<tr>
<td></td>
<td><img src="image" alt="Minimize coating &amp; laminating scrap" /></td>
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<tr>
<td></td>
<td><img src="image" alt="Flat rolls" /></td>
</tr>
<tr>
<td>Raw Material Savings</td>
<td>![Optimize coating weight(s)]</td>
</tr>
<tr>
<td>Process Information</td>
<td><img src="image" alt="Fast identification of process problems" /></td>
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<tr>
<td></td>
<td><img src="image" alt="Visibility into the base, coating &amp; laminating layers" /></td>
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<tr>
<td>Maximum Useable Width</td>
<td><img src="image" alt="Over coating (extrusion coat over the edge)" /></td>
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<td></td>
<td><img src="image" alt="Edge coating visibility" /></td>
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<tr>
<td></td>
<td><img src="image" alt="Control right to the edge of sheet" /></td>
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<tr>
<td>Production Performance</td>
<td><img src="image" alt="Fast start-up" /></td>
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<td><img src="image" alt="Fast product change" /></td>
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<td><img src="image" alt="Reliable flying splice changes" /></td>
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Two Types of Common Non-Nuclear Gauges: Total Weight and Selective

- **Total Weight Gauges:**
  - Beta / X-Ray Transmission and X-Ray Backscatter
  - Measure total weight
  - Determining Coat weight requires differential measurement
    - Measure base stock, then measure total weight and subtract
    - Requires at least two sensors/scanners

- **Direct Coat Weight Gauge:**
  - Infrared gauge
  - Directly measures the coating
    - A single gauge(scanner) does the job
## Differential versus Direct Coat Weight Measurement

<table>
<thead>
<tr>
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<th>Differential Measurement</th>
<th>Direct Measurement</th>
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<tbody>
<tr>
<td><strong>Calibration</strong></td>
<td>► Measures the total mass of the entire structure</td>
<td>► Discriminatory, multi-layer infrared measurement</td>
</tr>
<tr>
<td></td>
<td>► Nuclear measurements are non-discriminatory</td>
<td>► Polymer-specific calibration using infrared filter technologies</td>
</tr>
<tr>
<td></td>
<td>► True Net Coat algorithm provides simple, maintainable calibration</td>
<td></td>
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<tr>
<td><strong>Accuracy</strong></td>
<td>► Spot On™ provides accurate, responsive profile and average measurements</td>
<td>► Does not require Spot On measurement</td>
</tr>
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<td></td>
<td>► Good accuracy with coat weights greater than 10% of base material</td>
<td>► Immediate, first scan coat weight profile measurement and APC control</td>
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<td></td>
<td></td>
<td>► Consistent accuracy for all coating thicknesses</td>
</tr>
<tr>
<td><strong>Typical applications</strong></td>
<td>► Polymer on paper coatings</td>
<td>► Polymer on board coatings</td>
</tr>
<tr>
<td></td>
<td>► Total product measurement for obtaining flat rolls with APC</td>
<td>► Multi-layer coating measure; especially foil on board</td>
</tr>
</tbody>
</table>
Differential Coat Weight Measurement

- Basis weight or X-ray sensors prior to and following an extruder or coat station:
  - Beta:
    - Composition insensitivity
  - X-Ray Backscatter:
    - Single-sided measurement
    - Cost-effective solution
  - X-Ray Transmission:
    - High-resolution profile measurement

REWIND: Coat Weight or Coating Thickness
Tandem Extrusion Coating & Laminating Solution

Operator Work Station
Pro.Net TDI

TCP/IP Ethernet

Advanced Profile Control
- Auto Die Control
- iAPC

MD Coat Weight Control
- Extruder screw speeds

Intelligent Scanners Sensors & Control
- iFrame:
  - Scanner and Sensors
  - MD and APC control

Unwind Measurements:
- Beta 302
- Or X-Ray Transmission 312
- IR: NDC710S moisture

Coat 1:
- Beta 302
- Or X-Ray Transmission 312
- IR NDC710S
- Or NDC710S IR Moisture
- Same Spot Measurement

Coat 2

Laminate:
- Beta 302
- Or X-Ray Transmission 312
- NDC710S IR Moisture

Windup:
- Beta 302
- Or X-Ray Transmission 312
- IR NDC710S Top/Bottom
- Or NDC710S IR Moisture
- Same Spot Measurement
Differential Coat Weight Accuracy

► Accurate differential coat weight measurement needs two scanners to measure the same spot across the web:
  ▪ Coat weight measurement accuracy is the root mean square (RMS) function of Base accuracy + Gross accuracy of each sensor

► As the substrate weight increases relative to the coat weight, small errors in the substrate measurement causes large errors in the coat weight measurement:
  ▪ Potential negative coat weight measurements
  ▪ Large scan-to-scan coat weight measurements

► One solution is to filter the profiles. However this causes:
  ▪ Lengthy time averaging to produce a representative coat weight measurement
  ▪ Slow control response
Same Spot Measurement

Scanner 1 Starts Scanning

Results in precise tracking of Scanner 1 measurements by down line scanners

Even during line speed changes

Scanner 2 precisely follows track left by Scanner 1

Launch Distance
Direct IR Coat Weight Measurement

NDC uses the –CH band to measure these coatings:

- Label stock
- Wax barriers on paper
- Polymer extrusion on paper/foils:
  - Sugar wraps
  - Sacking
  - Packaging
  - Aseptic cartons
- Cold seal adhesives on paper/films
- Wall paper PVC plastisol coatings on paper
- UV cured lacquers on paper
- Acrylic coatings on paper pre-metalizing
- Epoxy resin coatings (carbon fibre applications)
Typical IR Backscatter Gauge on a Coating Application

Ranges / Accuracies:

- **Moisture**
  - Range: 0 – 90% moisture
  - Accuracy: 0.1%

- **Coating Weight**
  - Range: 0 – 1000 gsm
  - Accuracy: 0.1 gsm

Note: these values are product/substrate dependent.
Direct IR Coat Weight Measurement

- Scanning infrared reflection measurement following a coat station:
  - Measurement of coating components
  - Good streak measurement resolution
  - First scan gives accurate profile and coat weight measurement

- Better accuracy than differential gauges:
  - No inter-gauge/inter-scanner calculations

- Excellent pass-line / web flutter insensitivity
- Lower cost
- Non nuclear, “green” solution
710 Infrared Backscatter Sensor

- Backscatter sensor for measuring thin organic coatings and moisture:
  - Lacquer coat weights from 0.5-25 gm²
  - Ultra thin coatings from 5-1000 mg/m²
  - Clear & pigmented coatings
  - Moisture in substrates and coatings
  - Able to discriminate up to 6 multi-layer coatings

- Coatings on paper, board, textiles, polymer films and other scattering substrates:
  - Water or solvent-based
  - Solvent-less
  - Wax dip
  - Impregnation
  - Polymer extrusions
  - Impregnation
  - Barrier coatings
  - Lacquers
  - Hot melt
Traditional Length and Speed Measurements

- Accomplished by using a roller that contacts the material being measured
- The material turns the roller as the material moves
- An encoder or tachometer is attached to the roller
  - Generates pulses as the wheel or roller rotates
  - Relies on friction between the material and roller
Disadvantages of Contact Encoders/Tachometers

- **Error caused by slippage**
  - Dependent on friction
  - Wheel pressure
  - Product surface
  - Grease/ lubricant on surface
  - Mechanical inertia

- **Recalibration**
  - Diameter changes because of wear
  - Diameter changes because of debris build-up

- **Maintenance**
  - Bearings and other mechanical parts wear out
Problem Because of Slippage

- Slippage due to texture, slick coatings, lubricants, etc.
- Contact method relies on wheel circumference and # of rotations
- Contact measurement wheel:
  - Rides on product
  - Builds-up debris or wears down, requires recalibration

= 1.009% too short

d = 100 mm
1 circ = 314.16 mm
0.5 mm wears down:
d = 99 mm
1 circ = 311.02 mm
Non-Contact Measurement Technology

- Highly accurate, repeatable product length and speed measurements
- Measures product directly
- Uses Laser Doppler Velocimetry (LDV) technology
- True Zero Speed and direction measurement
- Better than +/-0.05% accuracy, +/-0.02% repeatability
- Permanently calibrated
- Independent of density or color of material
How Non-Contact Laser Measurement Works

- Non-contact gauge projects an interference pattern on the surface to be measured.

- As product moves, light is scattered back to the unit at a frequency proportional to the speed of the material.

Diagram showing:
- Laser Beams
- Non-Contact Encoder
- Standoff Distance
- Depth of Field
- Pass Line
- -Vel to +Vel
Non-Contact Laser LDV Theory

\[ d = \frac{\lambda}{2 \sin \kappa} \]

\[ v = \frac{d}{t} \]

\[ t = \frac{1}{f} \]

\[ V = d \cdot f \]

\[ L = \int_0^T v \, dt \]
Application Example: Film

Problem

- 1.5% length and speed inaccuracy
- 6000 m roll
- 90 m of uncertainty
- Each roll costs a significant amount in unnecessary expense
- Give away = roll length x material cost/sqm x contact encoder accuracy (1.5%)
Application Example: Film

Solution

► Install non-contact encoder at specific measurement points on the line
► Control length and speed of coating and lamination line application
► +/- 0.02% repeatability
► Instead of 90 meter per every 6000 meter of uncertainty
  ▪ **Lowers error to a max of 1.2 m on a 6000 m roll**
Application Example: Cross-Cutter Flying Saw Control
Application Example: Cutting Control

Problem/Solution
- Problem with slippage, mechanical inertia
- Control length direct to the PLC
- Instead of +/-1 mm at line speed of 140 m/min
- **Lowers error to +/- 0.2 mm by eliminating slippage and mechanical issues**
Other Application Examples

Nonwoven, Soft Surfaces

- Normal 2% length variation due to the density and surface

Rough Surfaces

- 2% to 3% length variation due to the roughness of surface
- Give away + inaccurate cut length

Additional control improves accuracy by 0.05%
Conclusion: Non-Contact Laser Encoder

Advantages

- Laser non-contact encoder is proven on many different types of manufacturing processes
- No slippage error - optical system and does not contact the product
- Permanently calibrated
- High +/-0.02% repeatability minimizes product waste, increases savings
- No moving parts to wear out: reduces maintenance and downtime, and lowers cost of ownership
Conclusions – Coat weight measurement

- Direct IR measurement is best if possible and provides:
  - Measurement of multi-layer polymer structures
  - Measurement of extrusion and board coatings
  - Moisture measurement
  - Cost-effective installation

- Differential systems:
  - Can handle a wider range of applications
  - With proper features:
    • Straightforward to implement
    • Acceptable accuracy
    • May be only possible method

- Justification:
  - Look at the investment from an ROI point of view, not cost
  - Select a gauging systems supplier with the expertise to deliver RESULTS
Thank You – Questions?

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