Presentation Topics

• **Purpose of talk**
  – Effective use of surface inspection systems
• **Defects; Causes and Cures**
• **Inspection System Overview.**
  – Lasers and Cameras.
  – Typical architecture.
  – Software and data mining.
Importance of Defect Reduction
The Role of Automatic Inspection

• **Concurrent benefits**
  – Maximize line speed, quality AND yields
  **WHILE SIMULTANEOUSLY**
  – Minimizing manpower, scrap, customer returns.

• **Wide variety of defects in coating and metallizing**
  – Voids, streaks, chatter, fibers, gels, spots, dimples, contaminants.
  – Substrate and coated stock.

• **On-line inspection systems can monitor process**
  – Locate defects, identify, mark location.
  – Process control; locate after a coating operation.
  – Quality assurance; locate at the end of the line to verify quality of shipped roll/sheet.
  – More effective and consistent than manual inspection.
  – Real-time.
  – Cost effective.
Effective Use Multistep Procedure

• Specifying System
• Purchase and install
• Defect(s) detected
• Defect characterization
  – Type, size, shape, “name”
• Defect map
• Historical database
• Experiments
• Implement changes
Understanding the Optical Challenge

Understand the manual inspection process.

How many different inspection setups?

Each inspection setup implies a unique optical channel.

- Direct transmission
- Low angle reflection
- Cross polarizers
- Indirect inspection

Zebra Target
Optical Channels

• An Optical Channel is a “view”.

• **Bright field** optical channels detect which change light **intensity** (contaminants, stains, pinholes, streaks, voids).

• **Dark field** optical channels detect defects which change light **path, scatter, diffusion** (scratches, gels, streaks, voids).

• **Laser and camera technologies** have unique strengths and weaknesses; *the optical solution must match the detection requirements.*
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Effective Use Requires Multistep Procedure

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Specifying System

- **Before buying system**
  - Accurate yield analysis
    - Identify main defects to be detected
      - Know highest loss categories
      - $ loss
    - Line speed range
    - Test samples
      - Extensive defect samples, various sizes, Jargon names
      - Prioritize Must, Wants
      - Defects or product anomalies to ignore
Defects: Causes and Cures

• **Bright field defects.**
  – Coating Pinholes on film.
  – Streaks.

• **Dark field defects.**
  – Substrate scratches.
  – Coating disturbances.

• **Multiple channel defects.**
  – Coating voids, optical film.
  – Gels.

• **Repeat defects and defect clusters.**

• **Sizing and classification.**
Coating Pinhole, 50 microns

Defect Signal
Scan Line
Zoomed

Laser detection and images
Coating Pinhole on Film

**Causes and Cures**

- **Description**
  - Tiny clear spots indicating the absence of a coated layer
  - Size differentiates from bubbles
    - **Much smaller**
- **Typical causes:**
  - Rupture of liquid coating caused by contamination
    - **Dirt, slivers etc. on surface or in coating solution**
  - Picking of coating by roll
  - Drying stresses & non-uniform flow rupturing the coating
- **Cures**
  - Clean substrate,
  - Filter coating solution
  - Uniform drying
Coating Streak on PET

Laser detection and images

Subtle

Severe

Fiber
Video Integration
Enhanced Scratch/Streak Detection

Raw Video Signal, Coating Streak

Enhanced Video Signal, Coating Streak

Streak Signal: Noise Low
Detection poor.

Streak Signal: Noise High
Easy to detect.
Mechanical Chatter
Causes and Cures

• Cures
  – Identify vibrations source & eliminate
  – Can get vibration spectra of coater components
  – to help locate source calculate vibration frequency on film
    • Measure machine direction distance occupied by N chatter bars.
    • Chatter wavelength is that distance divided by N-1.
    • Chatter Frequency is the line speed divided by the chatter wavelength.
  – Look for coating disturbances at the chatter frequency.
  – 60 Hz electrical.
Coating Streaks on Film

Cures

Get Defect Map: Full map, Md histogram, Td positions.

Lane 6, Streak

Intermittent Streak

Repeating voids

Lane 6, Streak Histogram
Coating Streaks on Film

Cures

• Start troubleshooting
• Clear bead and observe
  – if bubbles or contamination
• Reset gap
• Purge lines of air
• Check lips to see if knicked or build-up
• System should show when cleared and if improvement.
10µm wide Substrate Scratch
Dark Field Defect

**Bright Field**

Scratch does not absorb light
No bright field signal.

**Laser images**

**Dark Field**

Scratch scatters light
Strong dark field signal.
Scratches
Causes and Cures

- Linear gouges in coating
  - Can be short or long length
  - Differ from streaks edges ragged
- Caused by
  - Contamination on roller scratches coating
  - Difference in roll and web speed
- Cures
  - Clean all rolls in contact with web
  - Insure no rolls slipping
Dark Field Defect, Coating Disturbance

Chatter

Bar Chatter

Serpentine Chatter

Cross Direction

Machine Direction
Serpentine Chatter
Causes and Cures

• Series of irregular Td bars
  – Not as repetitive or straight as mechanical chatter

• Causes:
  – Hydrodynamic instability in coating bead
  – Operating outside of the stability region
  – Wetting effects on substrate

• Cures:
  – Correct process conditions to operate in stable region
  – Control viscosity/temperature
  – Maintain optimum applicator settings
  – Surface treat substrate for improved wettability
Mechanical Chatter
Causes and Cures

- **Mechanical Chatter Straight Td bars**
  - Slight variation in coating weight

- **Causes**
  - Mechanical vibrations from pumps, rolls, drives, h&v transmitted to coating bead
  - inducing vibrations in bead,
    - **Which effect coating weight causing bands.**
  - Chatter on substrate coating
    - **Can also appear as chatter in final coating**
Mechanical Chatter

Causes and Cures

• Cures
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Multiple Channel Defect, 50 µm optical film

**Bright Field AND Dark Field**

Both bright field **and** dark field are required for defect classification.
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Lasers and Cameras
Alternative Inspection Technologies

Laser Systems

Camera Systems
Laser and Camera Systems
Key Benefits

**Laser Systems**

- Multiple optical channels.
  - Reflection.
  - Transmission.
  - Bright field.
  - Dark field.
  - Polarity shift.
- Dark field defects (Scratches)
- Bright field defects (coating and substrate pinholes < 50 µm).

**Camera Systems**

- Lowest cost system.
- Excellent at bright field detection > 50 µm.
- Superior color/gray scale imaging.
Typical System Architecture

- **Telecentric Laser Scanner**
- **Cameras**
- **Illumination**
- **Coated Film**
- **Digital I/O’s** (Start/stop roll, markers, alarms)
- **Processing Console**
- **VPN Link**
- **Ethernet Link**
- **Operator Station**
- Defect data, data base & images for each roll.

- **Bright Field**
- **Dark Field**
- **Bright Field**
Defect Detected

• Defect map shows location on web
  – Defect location marked on web
  – Determine if random or patterned
  – Md & Td Location
• Insures correct defect worked on

• In some cases will lead directly to cure
Software and Data Mining

- Defect map.
- Transverse direction (Td) and Machine direction (Md) histograms.
- Data file for each roll, can be recalled at a later date; defects, sizes, locations, alarms, etc.
- Roll optimization; input roll length desired from each slit width and number of allowable defects; system locates the slit width locations.
- Data mining: Utilize on-board statistical package or third party software for customized analyses and reports; Excel compatible data bases, SQL.
Roll Repeats

- Small spot defects in the machine direction.
- From roll contamination
- Repeat at a fixed frequency
- Defect Map will give you
  - Repeat spacing
  - Location on substrate
Roll Repeats

• From contamination on roll surface
  – Disturbing coating
• Measure distance between spots
  – Equal circumference of dirty rolls
• Measure Td location
  – Where to look on roll
• Cure
  – clean rolls
  – Insure film dry
Substrate Defects

- Often oil, dirt or contamination on substrate will give defect when coated.
- Visually defect appears below coating
- In that case run clear substrate and get a defect map.
- If it matches coated defect Map
- Substrate is the cause
Streaks Defect Map

- Get Td location of streak
- Start troubleshooting
- Clear bead and observe
  - if bubbles or contamination
- Reset gap
- Purge lines of air
- Check lips to see if knicked or build-up
- System should show when cleared and if improvement.
Thank you!

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