

Coating Defects; Detection, Causes and Cures

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INTRODUCTION

Surface inspection systems are a new on-line technology for detecting coating defects such as voids, streaks, clumps, bubbles, scratches etc. in continuous web coating, metallizing and sheet-based processes. For a cost-effective process, all of these defects must be minimized to improve quality and yield, while simultaneously maximizing throughput. On-line inspection systems provide the technology so that the process can be monitored to determine defect causes and cures. This technology will enable the manufacturer to take decisive and timely corrective action and is a significant improvement over the end-of-roll sampling and visual analyses techniques.

BENEFITS

There are several benefits, which economically justify the investment in an on-line surface inspection system. Continuous use of the system will:

- Maximize coater or metallizer line speed, quality and yields
- Minimize coater costs; operating manpower, scrap, customer returns.
- Enhance market share; produce quality can be certified.
- Detect a wide variety of defects in coating and metallizing, such as voids, streaks, chatter, fibers, gels, spots, dimples, contaminants in substrate and coated film.
- Locate defects, identify, and mark location on web and log defect information into an electronic file and data base.
- Operate in real time
- More effective and consistent than manual inspection.
- Can vary location to insure maximum results

DEFECT DETECTION

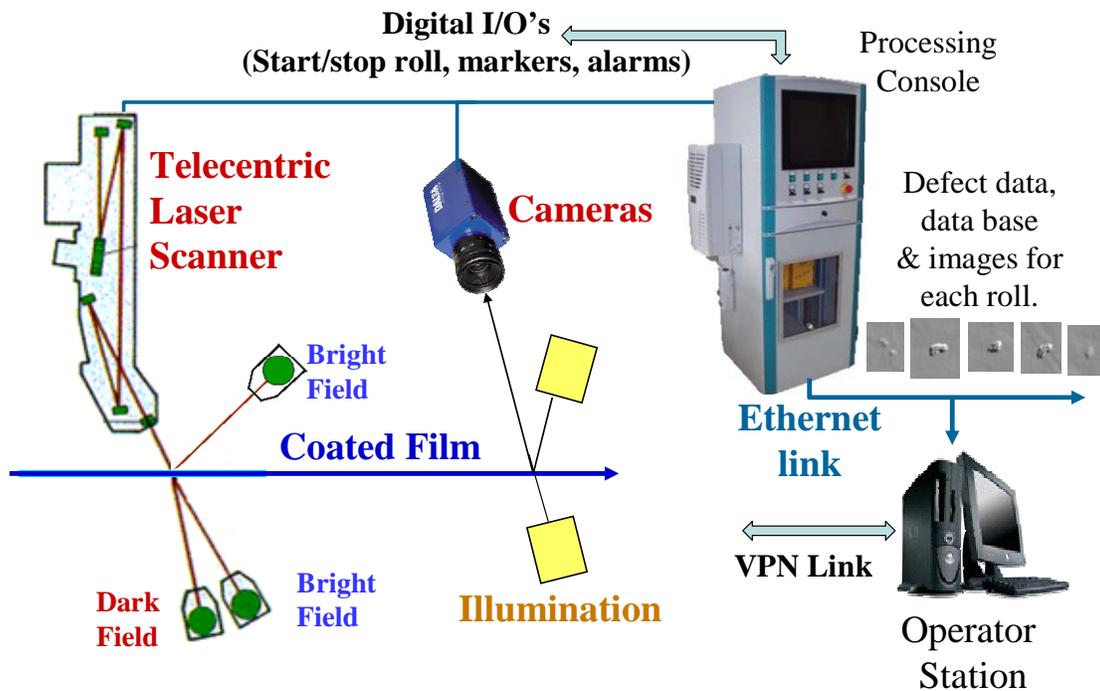
The surface inspection is achieved by using a two-part system. The detection system uses laser and camera inspection systems and computer technology to detect defects. These

systems provide on-line, real-time 100% inspection for visual defects, which are digitally stored in computer. Digital outputs provide alarms for pre-defined defect conditions, e.g. streaks, repeat defects, etc.

The second part of the system is the software, artificial intelligence programs and computer technology, which classify the defect, calculates defect parameters and provides a variety of parameters, while displaying the defect image so that corrective actions may be initiated. Figure 1 shows the typical system architecture.

Figure 1

Typical System Architecture



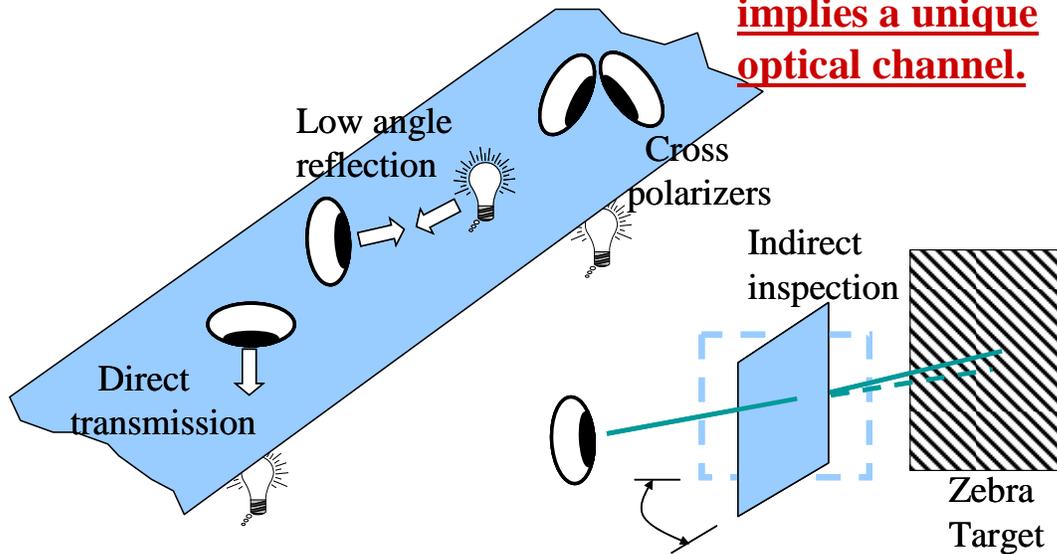
The sensitivity and the range of defects that can be detected depends on the design of the optical channels. Some of the factors, which go into the system design, are as follows:

- The number of channels/views required.

Getting the Optics Right Understanding the Optical Challenge

Understand the *manual* inspection process.
How many different inspection setups?

Each inspection setup implies a unique optical channel.



- The size of the critical defects that need to be detected.
- The optical nature of the defects.
- 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).
- Polarity channels detect defects that change the polarization angle.
- Laser and camera technologies have unique strengths and weaknesses; the optical solution must match the detection requirements.

The following figure shows the range of defects that can be detected and the optical considerations to detect them

The system specifications are developed by identifying defects that need to be detected and their size using laboratory systems.

CAUSES AND CURES

Once the defect is detected corrective action can start.

The analysis system can provide a list of defects and the amount lost to each, so

that the most onerous defects can be eradicated. It can also give a preliminary identification of defects types; it can also provide defect maps, which show location of defects in the coated web. In addition, once corrective action is taken, the inspection system provides immediate feedback on the efficacy of these actions.

ROLL REPEATS: For example, roll repeats are small spot defects in the machine direction, they repeat at affixed frequency and are caused by roll contamination effecting the coating. The defect map generated by the software system will give the distance between spots and the TD location of these spots. The distance between spots in the machine direction is the circumference of the roll causing the spots. The inspection system can be set to alarm on repeating defects and will provide the circumference of

the roll and the Td location of the spots. The circumference will identify possible rolls to check and the Td location on the roll, which is giving the repeat pattern. This will quickly show which roll to check for contaminants. If contamination is found then the roll can be cleaned and immediate feedback on the reduction of the defect.

DIMPLES: Another advantage to the on-line inspection system is that can help to correctly identify the defects. With the unaided eye repeats and dimples may appear similar. However, the differences can easily be seen as evidenced by the following image of dimples

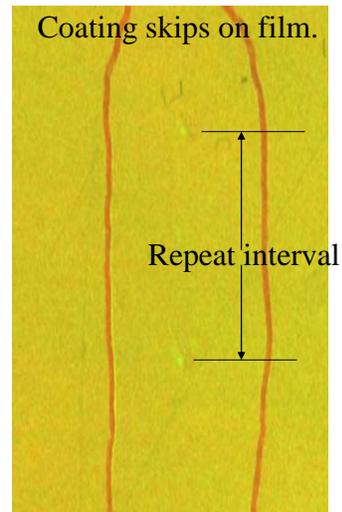
Laser and Camera Systems Key Benefits

Laser Systems

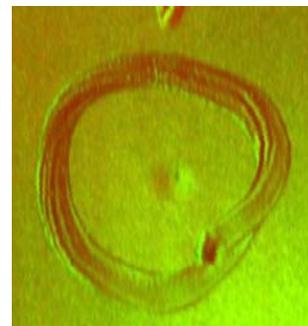
- **Multiple optical channels.**
 - Reflection.
 - Transmission.
 - Bright field.
 - Dark field.
 - Polarity shift.
- **Dark field defects (Scratches)**
- **Bright field defects (coating and substrate pinholes < 50 µm).**

Camera Systems

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



Dimple on film

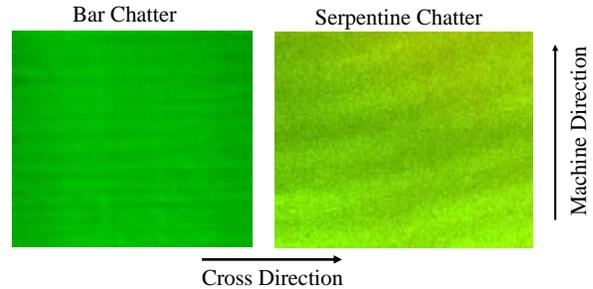


CHATTER: There are two different causes of chatter in a coating. Mechanical Chatter

Straight, which is straight Td, bars across the web. This is caused by mechanical vibrations from pumps, rolls, drives, H&V, being transmitted to coating bead and inducing vibrations, which effect coating weight causing bands. The second type is serpentine chatter, which is a series of irregular Td bars. They are not as repetitive or straight as mechanical chatter.

Serpentine chatter is caused by a hydrodynamic instability in coating bead, which causes the waves. It results from operating outside of the stability region of the coating process.

Dark Field Defect, Coating Disturbance Chatter



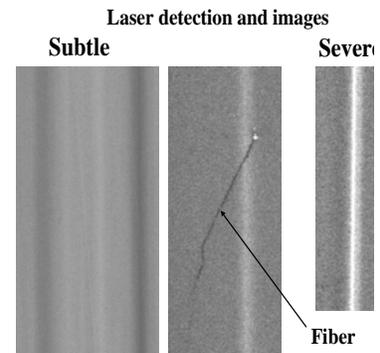
COATING STREAKS: Coating streaks are long continuous indentation in coating surface. These represent major yield losses in slot die coaters. As they are continuous, film loss will be great, but are often confused with scratches on higher speed lines, when viewed manually. Typical causes:

- Contaminants in gap bead, under blade
- Knicks in die lips or doctor blades.
- Contact on surface after coating

Most frequent cures:

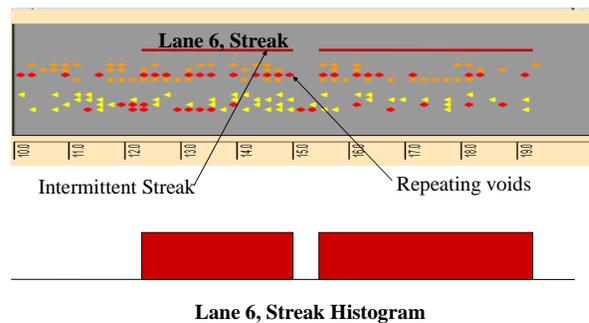
- Start troubleshooting
- Clear bead and observe if bubbles or contamination
- Reset gap
- Purge lines of air
- Check lips to see if knicked or buildup
- System should show when cleared and if improvement.
- Get the defect map.
- Determine lane and Td position.

Coating Streak on PET



Coating Streaks on Film Cures

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



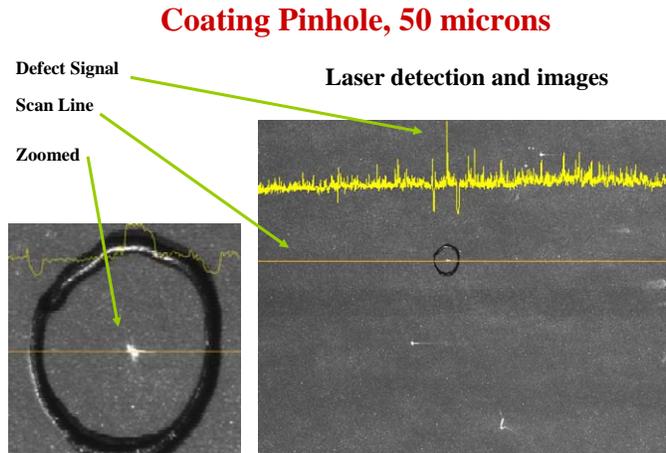
COATING PINHOLES: Coating pinholes are tiny spots indicating the absence of a coating layer. Their size differentiates them from bubbles; they are much smaller. In some processes, pinholes as small as 1 micron can be problematic.

Typical causes:

- Rupture of the liquid coating caused by contamination.
- Dirt, slivers, etc. on surface or in coating solution.
- Picking of coating by roll.
- Drying stresses and non-uniform flow, causing the coating to rupture.

Cures include:

- Cleaning substrate.
- Improving the coating filter operation.
- Uniform drying.



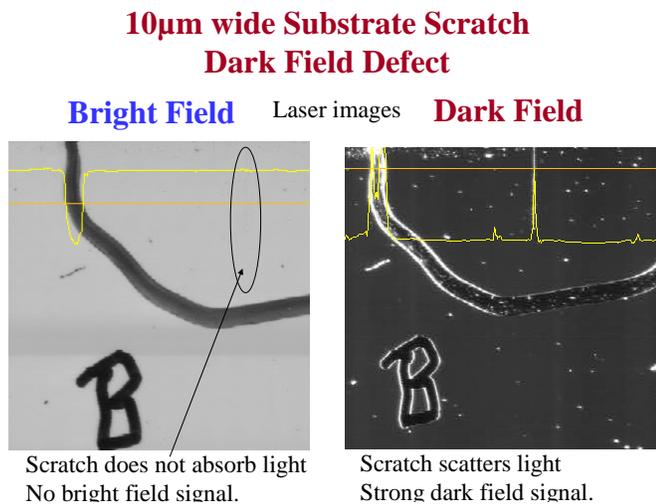
SCRATCHES: Scratches are **linear gouges in coating**. They can be short or long and often differ from streaks in their width (narrower) and their edges (ragged).

Typical causes:

- Contamination on roller scratches coating
- Difference in roll and web speed

Cures include:

- Clean all rolls in contact with web
- Insure no rolls slipping



SOFTWARE AND DATA MINING: Deriving information from the inspection system is easy; there are many utilities available, today. These include.

- **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.
- **Statistics and reports:** Utilize on-board statistical package or third party software for customized analyses and reports; Excel compatible data bases, SQL.

SUMMARY: Automatic laser and camera inspection systems can provide the means to concurrently maximize throughputs, yields and quality while minimizing manpower costs, waste and customer returns.