IN-LINE MONITORING DURING PRODUCTION OF COMPOSITES BASE MATERIAL AND PREPREGS:

HIGHER QUALITY DECREASES COSTS AND INCREASES CUSTOMER SATISFACTION

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Keywords: optical inspection, quality control, inline, defect detection, monitoring systems

Abstract
Automatic optical inspection (AOI) systems are applied as in-line production process control. Covering the full width of the material they detect irregularities in composite materials and monitor material properties (i.e. carbon/glass fiber web formation, coating thickness, ...).

1. Introduction

Automatic optical inspection (AOI) systems are well known tools for controlling product quality in web / film production lines (such as plastic films, metal bands, paper, and many more). Applying those solutions to monitor the quality of composite base materials and prepregs during production is not as common yet. However, due to the steep requirements placed on these materials and their complex layer configurations, precise control of the production process is essential to optimize production costs. AOI systems offer ways of improving product quality and customer satisfaction, while lowering production costs.

Figure 1. Optical in-line inspection system for quality and process control of composites

Excerpt from ISBN 978-3-00-053387-7

2. Basics of AOI Systems for Composites

AOI systems are mainly based on three components:

- Digital line cameras (CCD or CMOS technology)
- LED line illumination (several wavelengths possible)
- Evaluation electronics, comprising dedicated hard- and software

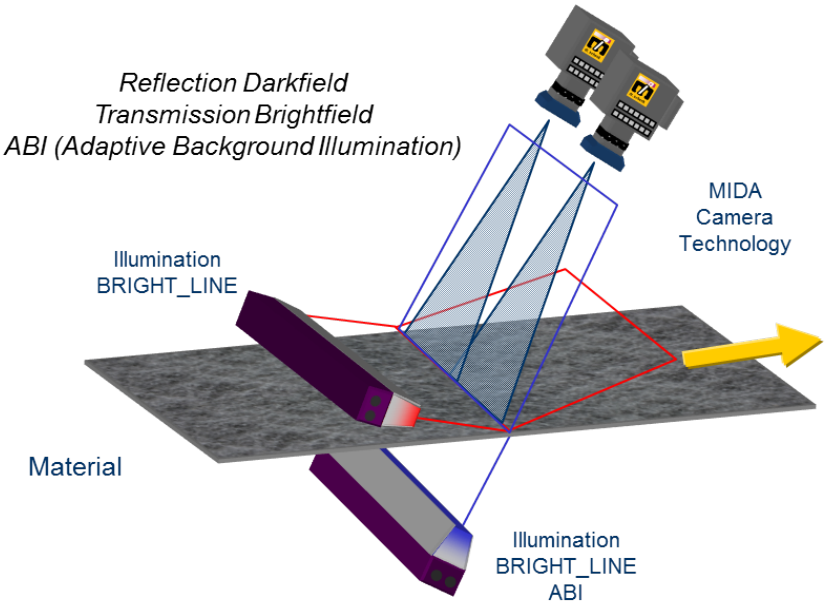

Figure 2. Schematics of an optical inspection system

Their key applications are:

- Small local irregularities and defects (such as lumps, foreign material, tear drops, broken filaments, particles, holes, coating voids,etc.) can interfere with or inhibit the function of the material, especially regarding its mechanical properties. Detecting these problems in-line is a safeguard against delivery of defective products to the customer. Inspection can be provided for the base material (e.g. glass or carbon fiber nonwovens or cloth) being the input step for prepreg production. This can be completed by optical control of the prepreg itself, again looking for defects such as missing impregnation, broken fibers, insects, and many more.
(see also examples in Fig. 5 and 6)
- In-line monitoring of material properties, covering the whole width of the material
Concurrent with the the detection of small local defects the AOI system can evaluate material properties over the whole width and length of the material, such as the thickness of the base material (formation, thickness homogeneity), surface homogeneity, coating homogeneity, etc.
(see Fig. 7)
- Process control for optimization of the production process
Both results (local defect detection and large area monitoring of material properties) enable very fast and efficient production control and optimization. Deviations in the production process are reported without delay, allowing immediate reaction to keep the production within the determined process window.

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3. State-of-the-Art and Innovation

AOI systems are already applied at many production sites. Currently CCD line cameras (recently also cameras based on CMOS technology) with increasing pixel resolution are combined with line illuminations. So far so good - but what is new, what are new capabilities pushing the envelope as regards saving money and time in plastic film production ?

Main new features of the latest AOI systems:

- LED line illuminations with multiple wavelengths
  Light sources are progressing rapidly. They feature rows of LEDs, now available in several different wavelengths. This makes it possible to inspect material using light of varying colors, which selectively increases the sensitivity of the inspection system for certain defects or material properties.
- Multiple Image Defect Analysis
  To enhance the performance of defect detection and evaluation, the AOI system can analyse the same defect using multiple images acquired in a single scan (Multiple Image Defect Analysis – MIDA; see Fig.3). For example, MIDA enables looking for defects with multiple light sources (e.g. with different colors or different angles of incidence) at the same time. This helps to optimize the yield of a web production line, independent from the production process type.

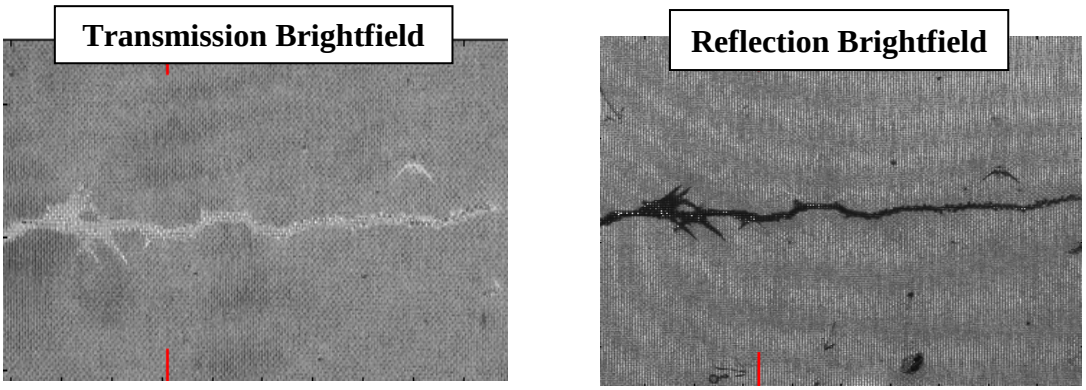

Figure 3. Multiple Image Defect Analysis (MIDA) of the same defect (crack in prepreg)

- Concurrent material properties monitoring
  While detecting local defects, modern in-line AOI systems can also monitor and return absolute values for the properties of the materials, for example the homogeneity of the composite base material and coating properties. They perform this function over the complete material width. In contrast, conventional optical process control systems monitor coating properties by measuring only a few spots on the material, mostly with a significant time delay after production of the material (Fig. 4).
- Enhanced quality analysis methods
  New and enhanced quality analysis methods are based on the evaluation of gray value distribution over the whole sample, e.g. by histograms, giving the spatial frequency of gray values within certain sub-areas of the material. This new approach allows sophisticated detection of defective areas even in/on composite materials, having structured/textured surfaces (Fig. 8)

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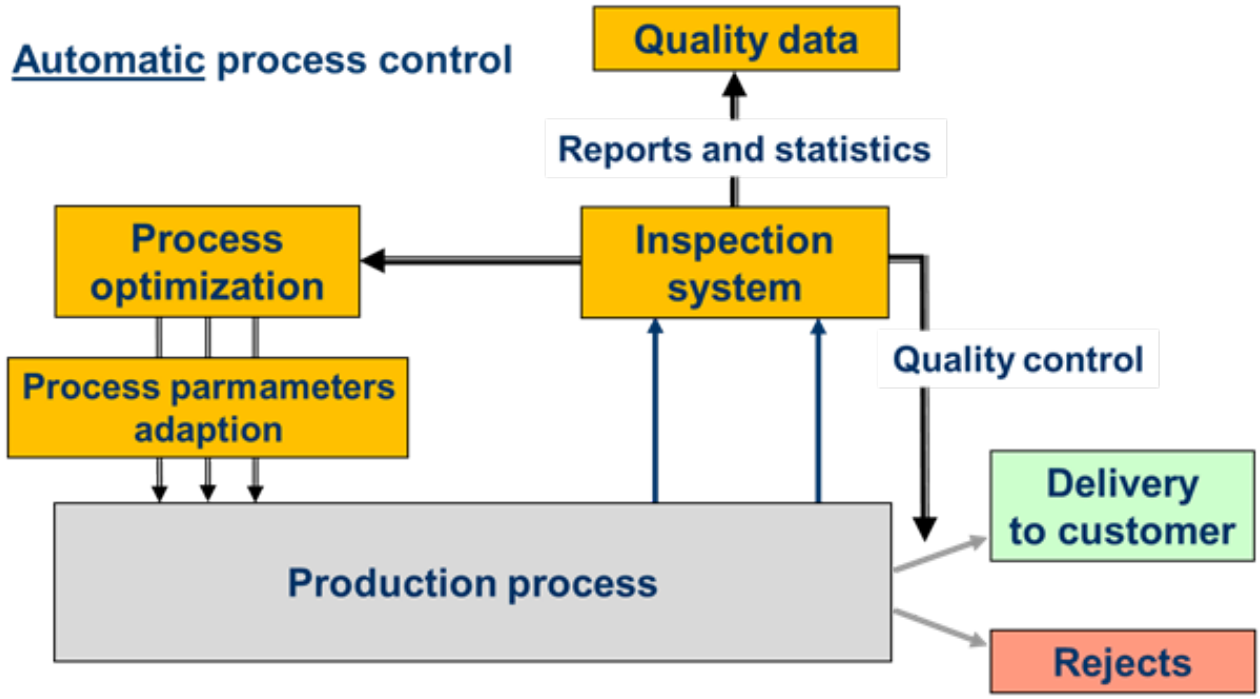

Figure 4. Automatic process control of a production process by AOI data

4. Examples of defects detected with AOI

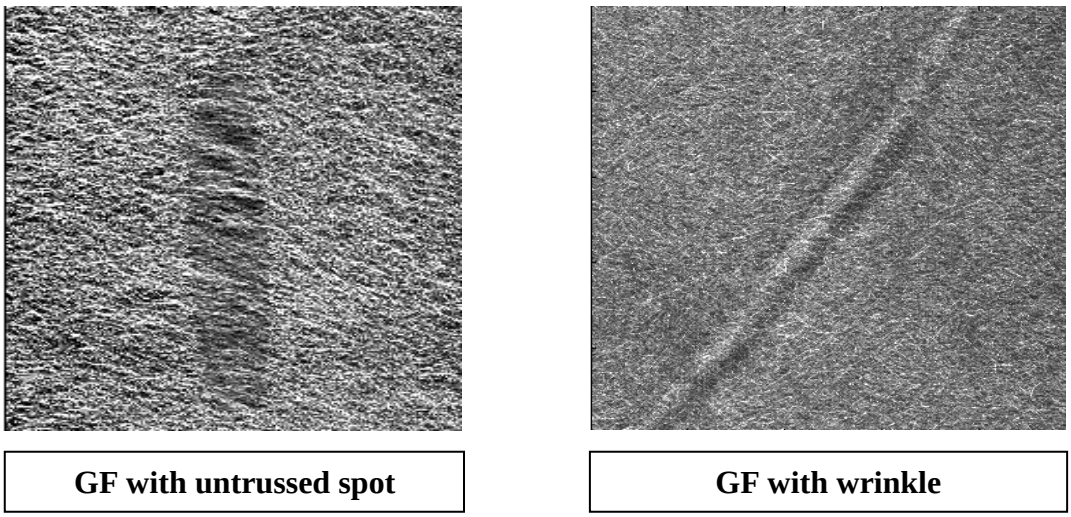

Figure 5. Defect examples detected in GF/CF mats

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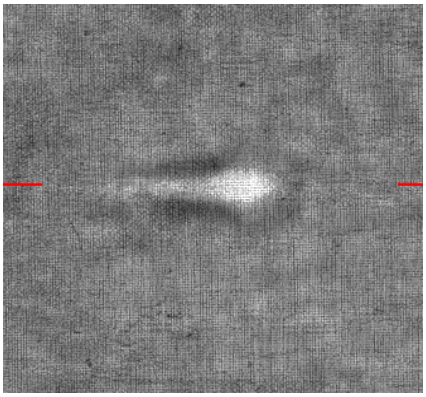
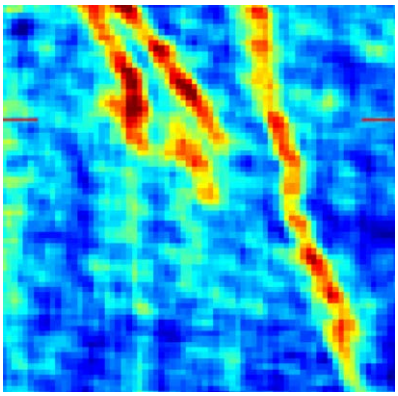
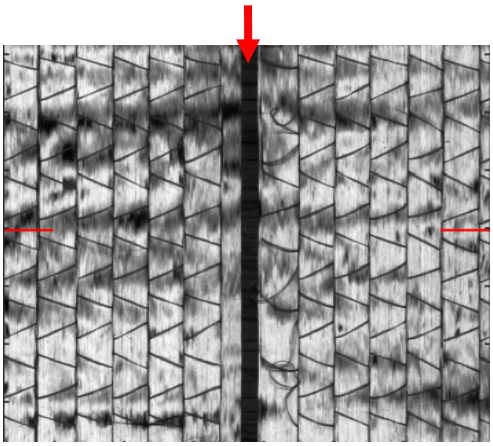
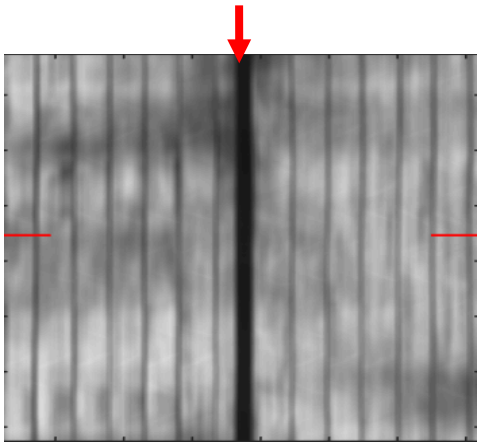


Tear drop in prepreg



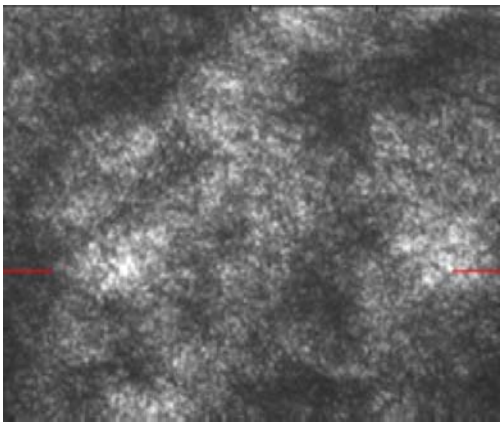
Impregnation inhomogeneities

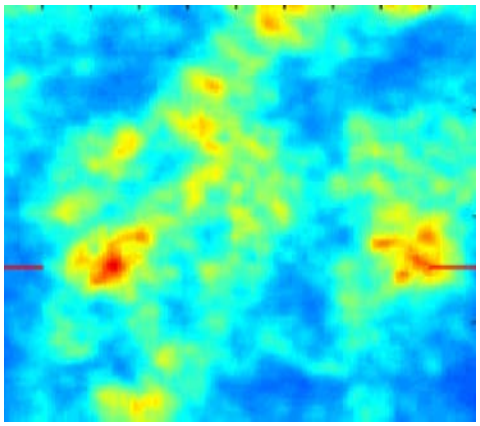




Missing thread (raw image + processed image)

Figure 6. Defect examples detected in GF/CF textiles





Thin area in fibre mat (gray image + homgeneity map)

Figure 7. Thickness inhomogeneity in GF/CF mat

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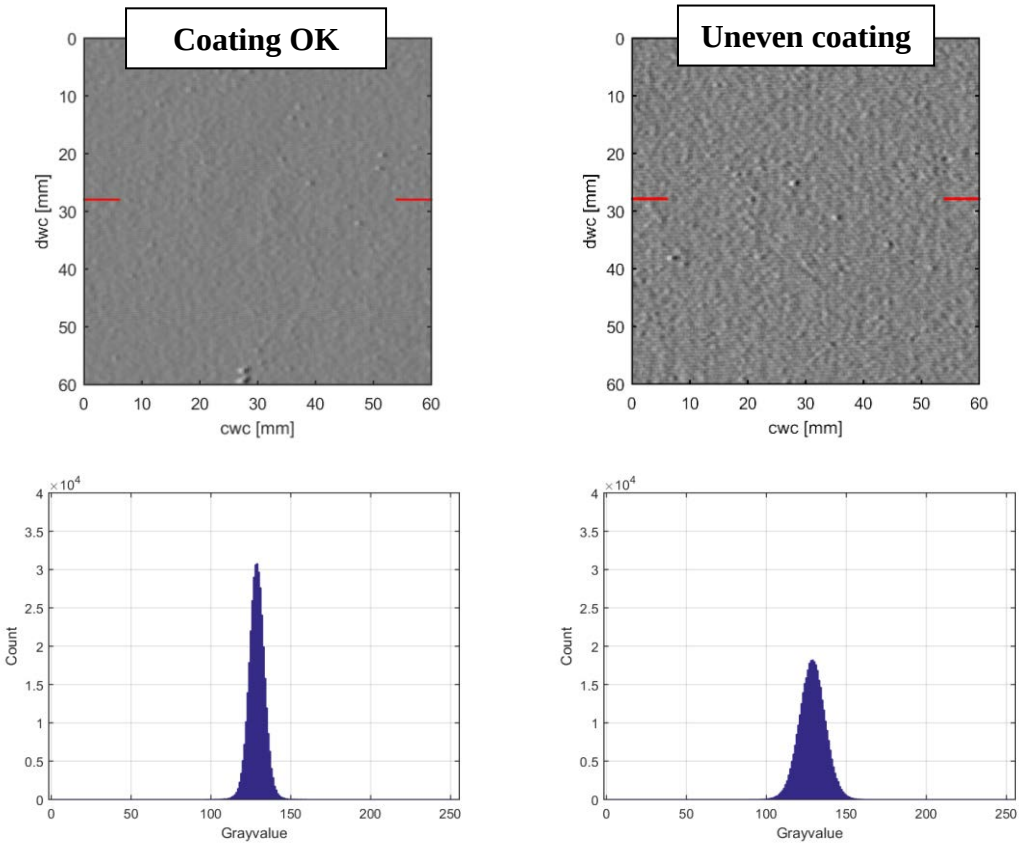

Figure 8. Coating surface evaluation via gray values histogram

5. Conclusions

Automatic Optical Inspection systems (AOI) can be applied as inline process control. The information gathered by these systems offers the possibility to automatically optimize the production process. Furthermore, defects and material irregularities can be detected and marked as input for further processing of the material. And lastly, the inspection data is an important input for cutting the composite or prepreg web; knowing the precise position of material with defects / irregularities will help to maximize the yield in this step.

Investment costs for an AOI are retrurned within a short time; several examples of installations illustrate a return of investment (ROI) of less than 2 years, often even below one year.

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