Automated Surface Inspection
AIMCAL Technical Conference
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October 2007

Manuscript for Automated Surface Inspection

Automated inspection of surface defects in film, paper, and converted products has been used for over 20 years. These systems have enabled the inspection of 100% of the surface area of a coil, both surfaces as required. The benefits and performance of inspection systems have increased dramatically as camera resolution and scanning speeds have increased, image processors have become more powerful, system user friendliness has improved, and common desktop computers have became capable of displaying and archiving the inspection data - all this, with a decrease in system pricing; up to 50%, conservatively, and more in the case of large systems inspecting wide, fast webs.

Old criticisms of automated inspection systems persist – users state the pricing still remains too high, it is time-consuming to develop the instructions for the system, and there are challenges in effectively using all the data. These criticisms are muted through careful management of the system's introduction to the quality monitoring process and the assignment of a system champion who takes aggressive ownership of the system, Benefits realized including the reduction of defective material delivered to customers, the reduction of scrap, and the availability of timely inspection data which can point to corrective actions one can take to improve the coating process and reduce defects – not after the analysis of reams of data, but immediately.

Changing Technologies and System Architecture

Inspection technologies have coalesced over the past 10 years. While laser scanning-based systems were introduced over 20 years ago and area or frame-based cameras are still used, most inspection systems nowadays use linear cameras which scan in one dimension and are networked across the coil. The resolution of linear cameras is typically now in the range of 4000 to 8000 pixels; the scan rates are 10's of thousands of lines per second; and processing rates of the cameras or associated vision engines are 60 Megapixels per second and higher, made possible by incredibly powerful field programmable gate arrays (FPGA). Applying a little math indicates that two to four high resolution cameras will adequately inspect the full width of a 50 inch web and detect defects .010 to .020 inches in size. Together, cameras and image processors, whether on-camera or in separate vision engines, will detect the defects, classify them using industry nomenclature, and enable the display and recording of all the data real time while the web travels at 200 to 500 fpm.

The system architecture can be quite streamlined as indicated by the schematic in the PPt presentation showing a smart camera-based system. Rather than communicating images to a circuit board or vision engine for processing, smart cameras perform the image processing on-camera and send just defect data, including defect images, through a standard Ethernet link to the host PC for display and recording. Note the line encoder, which synchronizes the scan rate of the cameras with the travel speed of the web.

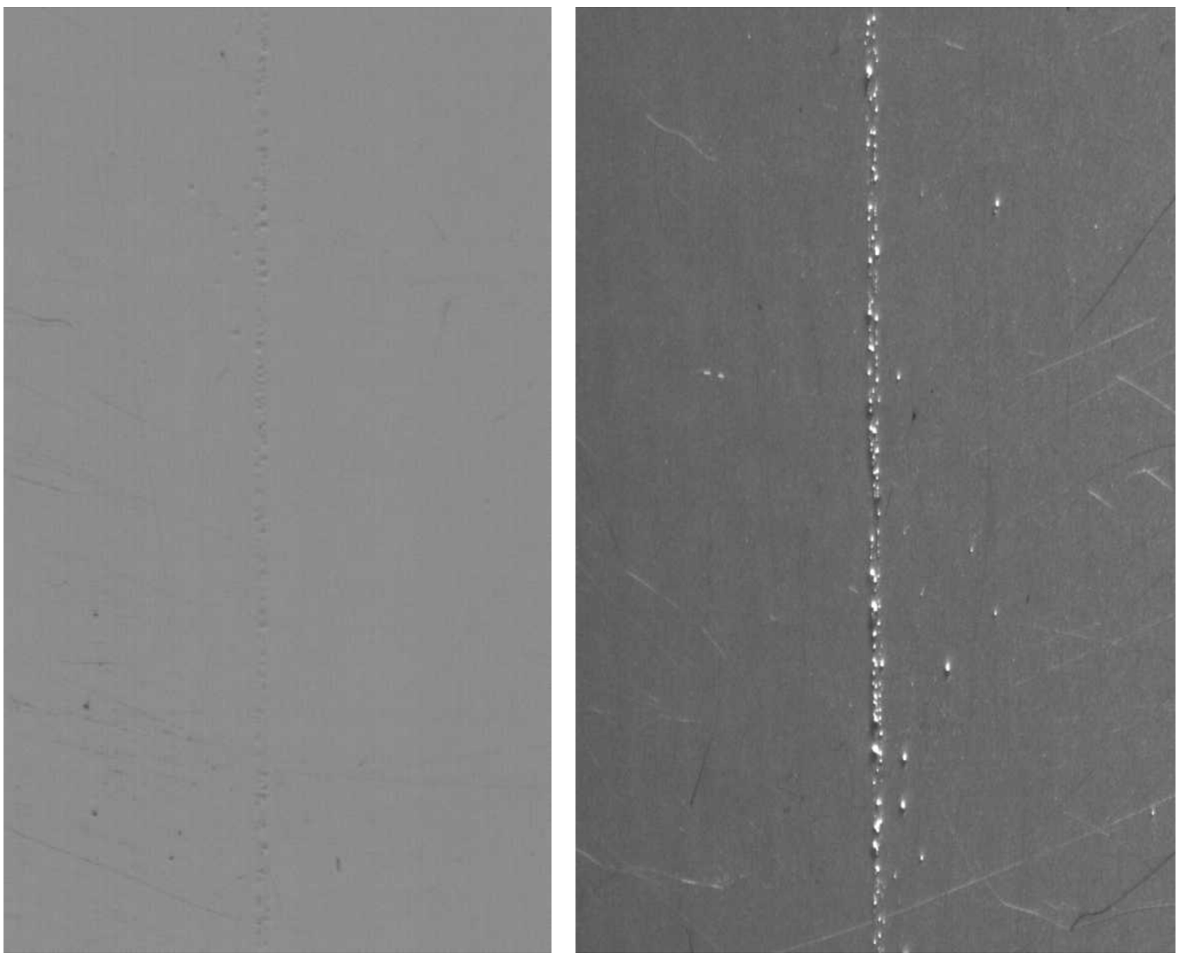
System Infrastructure

The support structures for an inspection system position the cameras and lighting, ensuring the optimum orientation and alignment of the camera field of view with the lighting pattern. Four or eight inch tubular steel is used for the vertical supports and generally the structural members are isolated from the line machinery. Even if a system requires multiple stations of lights and cameras (due to the variety of defects), its footprint is fairly modest in size with integrated stations of cameras and lights typically installed within two to three feet of one another in the direction of coil travel.

While industrial digital cameras demonstrate excellent reliability and durability, like most high performance electronic components, they are sensitive to heat (sometimes performance is impacted by factory floor temperatures 100°F and above). Given the relatively benign environments, most installations on film lines do not require that the cameras be enclosed/receive cooling air; but inspection system suppliers will provide enclosures, when required. Note the rectangular-shaped enclosure in the below image showing an installed system. The linear cameras' fields of view are accommodated by the narrow slit at the base of the enclosure. Positive pressure is maintained in the enclosure by the internal fans and/or factory air. The flow of air exhausting through the slit, prevents the intrusion of dirt and dust.

Illumination

Camera specifications, image processing algorithms, and defect data displays tend to dominate discussion about inspection system capabilities, but illumination is at the very core of designing an inspection system. In fact, lighting can be the magic bullet with the proper selection of lighting serving to maximize the contrast of defects to the background web material. See the below figure which shows images of the same defect illuminated by fluorescent bright field lighting in the first image and by a proprietary lighting technique using an LED light line in the second image. This dramatic difference between the two images in the contrasts between defect and background points to the importance of selecting the lighting technique(s) to use.



While illumination using an LED light line takes full advantage of the advances in illumination technology introduced by intense, controllable, and long-life LED's, there are often occasions when 'low tech' illumination is the lighting of choice.

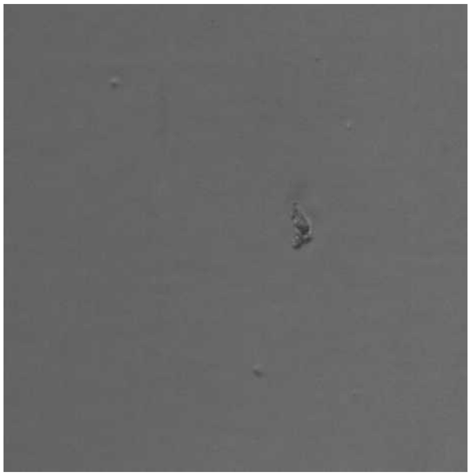
For example, bright field fluorescent lighting creating a very diffused illumination pattern can often be very effective in detecting two dimensional defects.

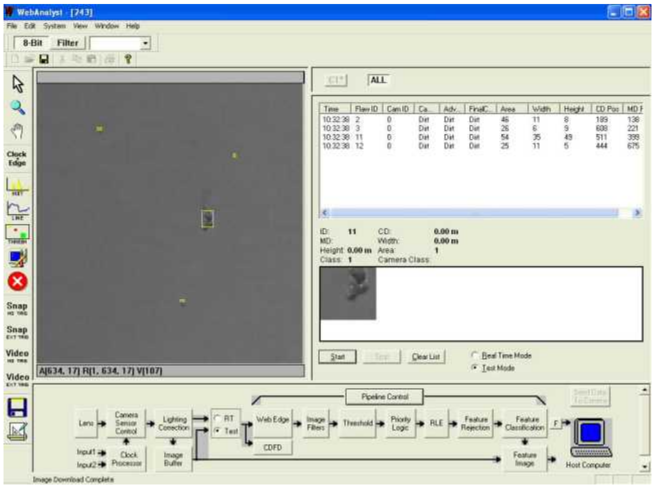
Sample Imaging

The imaging of sample material showing representative defects is the key step along the path to selecting the optimum system configuration. While the width and travel speed of the coil are two key variables in determining the resolution of the system, the size of the smallest defects (diameter in the case of spot defects, the narrowest width in the case of elongated defects such as streaks and scratches) is another important factor. A good rule of thumb, particularly in the case of very subtle defects, is to span the smallest defect with at least two pixels to ensure detection. Using these variables (web with, speed, and defect size) in a calculation yields the system resolution and number of cameras required to span the web.

If this calculation was the end in determining the number of cameras required for the system, the definition of a system configuration would be relatively simple. However, lighting tends to be specialized; and the optical characteristics of defects come to the fore. Sometimes more than one lighting technique is required to maximize the contrast of multiple defects types. As a result, the number of cameras, and thus the system cost, are increased in a situation when multiple lighting techniques are required to be used.

Returning to the subject of the imaging of sample materials – It is an absolute necessity that the future system user furnishes the inspection system supplier with samples showing a good cross section of the defects which are required to be detected. Experience has shown that in a laboratory environment the imaging of sample materials, accomplished by experienced applications personnel, can conclusively point to an effective system configuration. The imaging of samples will identify the number of cameras, type-illumination, and the orientation of cameras & lighting required for system effectiveness. Reference the following raw and processed images from sample imaging:





System Installation and Commissioning

With the system structures in place and the electronic components delivered, system installation is accomplished in a matter of a few days with coil production generally restricted for just one or two days while the supplier accesses the bridge structures supporting the cameras and lighting over the coil. Commissioning the system takes more time as the supplier proceeds to use the system set-up software to instruct the camera and processing functions what defects need to be detected and what information needs to be displayed. Training on system set-up procedures is imperative as user personnel are given the knowledge required to properly instruct the system in detecting the defects and displaying the data. Recipes or sets of inspection parameters are developed for the different materials and associated defect characteristics. Depending on the number of cameras in the system, installation, commissioning and training are generally completed in five to 10 days.

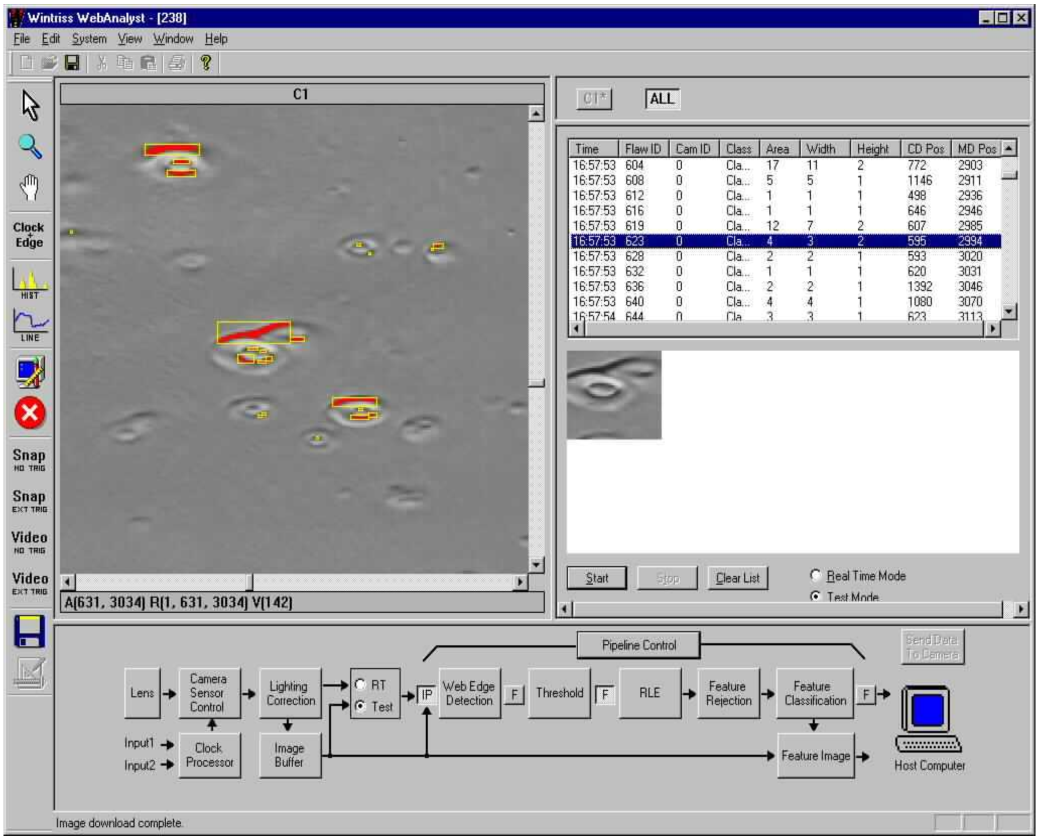
As one would expect, training and recipe generation don't end with the supplier's physical departure from the factory. Inspection systems offer remote Internet data access to the supplier who can view the same information displayed to the user on the factory floor. Generally, occasional phone communications with concurrent viewing of system displays by supplier and user continue for several months after system installation as recipes are developed and refined. Users tend to perform verification testing fairly quickly after installation by comparing eyeball inspection results to the system reports. Defect classification is verified, as is the locating data for the defects. Verification testing helps build the confidence of the user in the system's detection accuracy and the validity of system reports.

System Operation

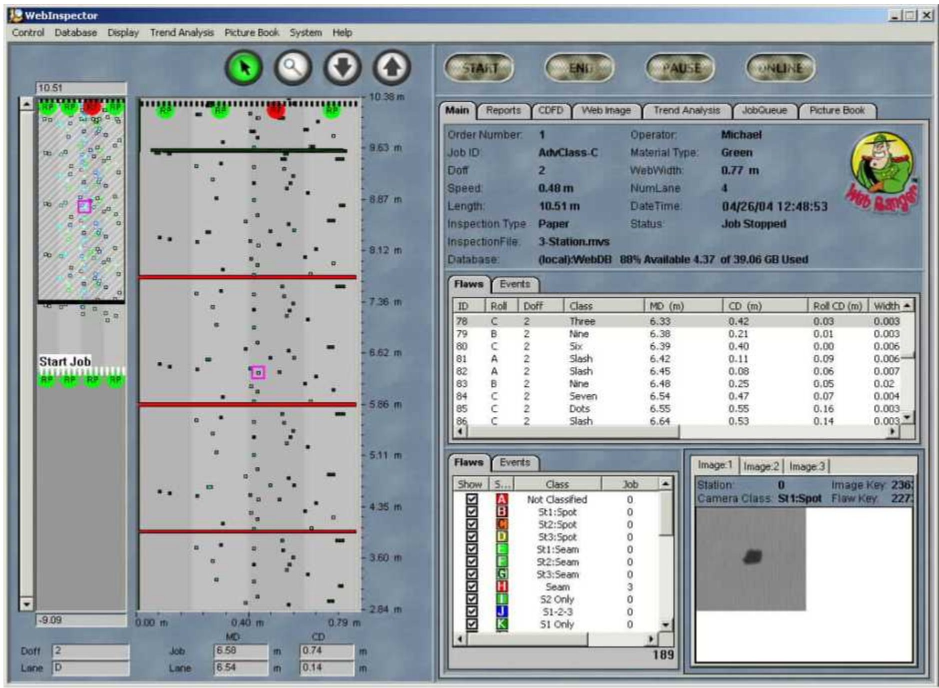
In the case of a smart camera-based systems, on-board image processing enables the cameras to analyze the acquired images and then communicate the defect data, including images of each defect, over the system Ethernet link to the host computer. In addition to information associated with the defects, the cameras provide a time stamp, defect classification/ nomenclature, and defect location defined in terms of the coil machine direction and cross direction.

Each of the cameras accommodates multiple digital inputs from the host computer and supply digital outputs. The digital inputs are used for accepting user-defined signals such as a job-change. The digital outputs actuate alarms, and when a marking device is installed, they will fire the device to mark the edge of the web adjacent to where a defect is detected.

The system runs two major software applications residing in the host PC, the set-up and operating programs. The set-up software instructs the system on what defects it needs to detect and how the data is displayed. See the graphical user interface (GUI) display below for the Wintriss set-up software.



The operating software provides on-line monitoring including defect viewing, defect mapping, data archiving and statistical data. Data archiving is accomplished in a SQL (Structured Query Language) data base. The GUI for the Wintriss operating software (see below) displays a job map, a list of all detected defects with their associated metrics, a count of defects for each defect category, an image of the most recently detected defect, and system status information. This display can be user-modified to perform trend analyses on different defect types, show defect density information, and aggregate recent defect images to enable operators to perform at-a-glance assessment of product quality.



Visual and audio alarms can be programmed to alert operators to the detection of specific defect types. Reporting features allow users to view reports with an inspection in progress – both automatically-generated reports and manual reports. The SQL data base contains all the relevant defect information, providing access to historical data based on SQL queries. Custom reports, including graphical depictions of statistical data, can be generated using third party reports, including Crystal Reports. Additionally, systems offer the user the capability to access the data remotely from any location with access to Ethernet and enable managers to view inspection results on-line and generate historical reports.

Inspection systems enable rolled goods manufacturers and converters to precisely and comprehensively define the quality of their product. While the set-up and operation of these systems entail more than ‘point and click’ functions, and the training required is extensive, the benefits can quickly justify the investment. Inspection systems have captured the full benefits of improved imaging and processing hardware and software while becoming significantly more affordable over the past 10 years.