AIMCAL Extended Abstract

Innovative Automated Web and Sheet Inspection Systems- Vision Beyond Defect Detection

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ABSTRACT

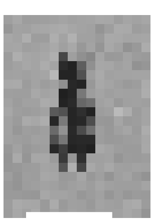
Modern web inspection systems now deliver much more. Enabled by recent advancements in LED illumination-technology and very high speed cameras, the newest systems reach much higher image resolutions. Because of this, particularly for small defects, advanced classification becomes possible thus elevating mere detection into reliable identification of the root cause. Scan rate synchronized light switching technology, one of the most recent innovations few systems master, provides simultaneous acquisition of the sheet at multiple illumination modes with a single bank of cameras which significantly increases detection and classification performance without the traditional high cost of multiple camera banks.

INNOVATIVE INSPECTION TECHNOLOGY

Automated web and sheet inspection tools are typically used for the detection of localized defects. After detection and classification they report the location of the various defects. With that they are primarily used as a quality disposition tool. Modern systems can deliver much more than that.

The newest systems reach much image resolutions as now pixel-rates per camera of up to 320MHz can be achieved. That means that for example 8k pixel line scan cameras can be used for high speed coating operations and still maintain a very high image resolution. Because of the higher fidelity of the images, particularly for small defects, advanced classification becomes possible, thus elevating mere detection into reliable identification or the root cause.

The following shows a typical coating defect captured at a speed of 300 ft/min. Until recently 40-80MHx/4kPix Cameras were standard. Using 4 Cameras at 300ft/min this provides an image resolution of about 3/1000”. With ultra-high frequency cameras the resolution can be cut in half to about 1.5/1000” using 4 320MHz/8KPix cameras at about the same cost.



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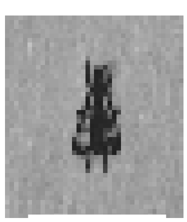
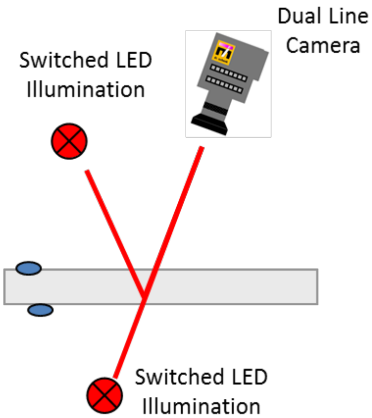


Insect !

The newest high speed processing hardware can process a significantly higher amount of imperfections as possible from even a few months ago, resulting in the ability to identify high counts of more process- rather than quality-relevant imperfections. Real-time running parameters and defect density maps provide valuable process feedback as well as early warning indicators for potential problems.

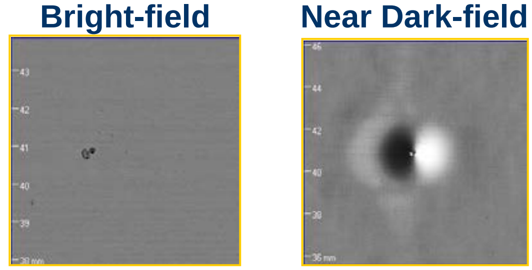
With all this increased speed come significantly reduced exposure times. As in a standard photo camera, the faster the sutter speed the more light is required, or one uses a higher speed film. Moder C-MOS technoloy vision sensors provide a much higher sensitivity. With duel-line TDI sensors this sensitivity can even be doubled by essengtially performing a double-exposure of the same spot.

In addition LED-technology has evolved from very-low light power illuminations to the most powerful illuminations available for line scan vision applications. About 3ft of a high-density LED line as developed by Schenk provides the equivalent light output a 10 kW halogen bulb. With that very intense light can be projected onto the web without the heat an incandescent illumination would generate. In adition LED do not have any significant output in the infrared. This prevents the possibility of heating or even burning the coating with a high intensity illumination.



Scan rate synchronized light switching technology, one of the most recent innovations few systems master, provides simultaneous acquisition of the sheet at multiple illumination modes with a single bank of cameras which significantly increases detection and classification performance without the traditional high cost of multiple camera banks.

Bright-field **Near Dark-field**



With the opportunity to have multiple views looking at the precise location at the same time (without having to calibrate multiple camera banks against each other) moves the vision system one step closer to the way a carful examiner would try to classify a defect: By observing the same spot with different illumination techniques. A very typical problem for coating defects is to separate a particle that merely sits on the surface from those embedded in the coating. In a simple diffuse light bright field transmission both would look the same. Once near dark-field directed light illumination is added the impact of the embedded particle to the coating itself becomes visible and it can now be easily classified as such. The Bright-field image of the embedded particle provides the size of the particle itself while the near dark-fiel one provides the size (and severity) of the coating disturbance.

The most significant innovation for line scan vision systems is however not even related to local imperfections but that they can actually provide a real time 100% map of coating or raw material variations by essentially using every camera pixel as a small calibrated gauge. These full surface coverage homogeneity maps provide an insight into the dynamics of web and sheet processes previously unheard of.

VISION BEYOND DEFECT DETECTION

With this, automated surface inspection is now far more than spotting local defects. A reliable detection of bubbles, streaks, or pinholes in coated material goes without saying when we speak of today’s vision systems. However, yield increase and even faster return-on-investment can be achieved with inspection systems that offer additional process monitoring features. Because of the new innovations in inspection systems previously discussed, additional optical properties of the material can be measured using the same hardware as the defect detection system. Additional monitoring options for the coating process for example are: local layer thickness, porosity of films and coatings, reflectivity, resistivity, and haze.

Gauging and defect inspection systems are both well established production tools to increase productivity while maintaining high quality standard. Gauging systems usually provide a single spot, well calibrated measurement. In order to get a complete cross-web profile, the sensor head is moved across the web in a meandering fashion. The actual portion of the entire web that is measured is actually very small, typically less than one percent.
Defect inspection systems on the other hand cover 100% of the surface but typically use background subtraction algorithms that concentrate on relatively localized imperfections. The images created by the systems are usually not calibrated in a fashion that they can be used for gauging. What is missing is technology that covers 100% of the surface while permitting reasonably calibrated measurement capabilities.

The key to 100% coverage to obtain these measurements is that basically every pixel of a line scan camera can be calibrated individually. Common practice to calibrate a measurement is two-point calibration using a span (C_s) and offset (C_f) calibration factors.

$$M_{cal} = C_s * M_{raw} + C_o$$

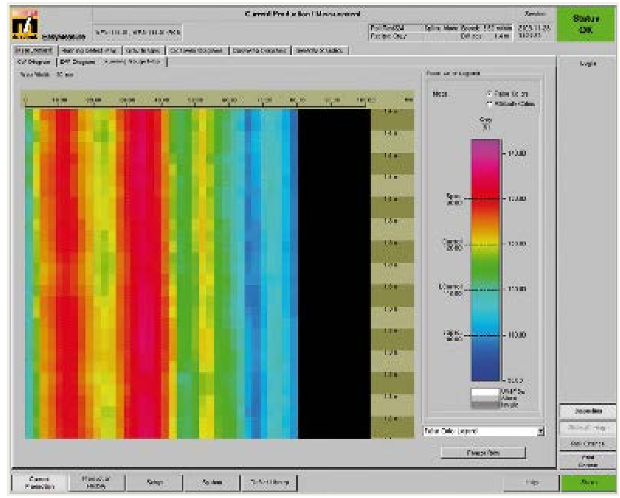
However normal background subtraction uses what is essentially a dynamic offset calibration only as it is much easier done at the very high pixel rates vision cameras run. Schenk uses, for example, cameras with up to 320MHz pixel frequency. Only recently, with modern hardware components, it has indeed become possible to actually multiply each individual pixel at the full rate of pixels.

Once individual pixels of a high resolution web inspection system are properly calibrated against each other the resulting number of measurement points is certainly a lot too high to provide any meaningful data. What could one do with the approximately 1 billion measurement points a 4 camera system could generate in a second? In order to generate meaningful measurements the data needs to be analyzed by using the high resolution data in a sectored statistical analysis. The entire web surface is thus divided into smaller sectors in a tile-like fashion. One can for example divide the entire web width into 10 or even a few hundred individual lanes and down-web sections of a few feet or inches. Each sector represents still data of a few thousand or more individual measurement points. The sectors themselves serve as what one can call a "meta-pixel" meaning a pixel whose grey values represents a multitude of original high resolution pixels. The easiest to interpret is the average, as it essentially nothing else but a "birds-eye" view of the web.

EASYMEASURE

The EasyMeasure gauging system is the first non-radioactive, non-scanning system in the industry that offers full width monitoring, has all process control features in one system, and that can be combined with defect detection in one system to reduce costs. The technology provides tangible, real benefits that provide an actual return on investment for the user.

The system options monitor: porosity of films and coatings, local thickness variations, coating sheet resistance, coating surface structure, and reflectance of materials and coatings. It is the latest, innovative option for manufacturers looking for quality and process control, data collection, and web marking. The system software provides graphical visualization of the web material's quality. Each roll produced has its own identity and quality grade thus eliminating shipping mistakes. The inspection system simultaneously identifies roll defects and critically stressed larger drafted areas in a color coded roll defect map. EasyMeasure can use the same optical components from the inspection system, which will ultimately keep the manufacturers investment low and reduce costs. In addition, by monitoring the physical characteristics online and in real-time, manufacturers reduce, if not altogether; eliminate the need for off-line testing and verification. And unlike other systems out there, it covers 100% of the material width.



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