FASTER AND MORE ACCURATE DECISION-MAKING USING INTEGRATED SOLUTIONS THROUGHOUT THE PAPER MANUFACTURING PROCESS

Authors*: Michael Trunkhardt1
Christoph Wiericks1

ABSTRACT
In the past, many paper manufacturers viewed automatic inspection or web break monitoring as the universal remedy for any application in which both increased production speeds and high quality are required. However, the improvement potential has not yet been reached using these technologies. Automated processes integrated in web product manufacturing can only be accurately optimized if meaningful information about production defects, along each processing stage, is available well in advance. The solution: linking Web Inspection Systems (WIS) to Web Break Monitoring sensors (WBM) to form a single highly integrated system. The advanced information from the WBM sensor system is transferred to the WIS. During the process, the WBM performs the tasks involved in capturing events. Then, the overall system acts as a platform in which all of the relevant information needed for monitoring (inspection, analysis, web breaks and events) is collected. This information is used to forecast possible trouble spots during production. With optional tools, based on the collected inspection data, production efficiency as a whole can also be increased.

Keywords: Production optimization, quality, web break analysis, web break monitoring, web inspection system

INTRODUCTION
Paper manufacturers must take steps to continuously improve their competitive advantage. This is simply because competition around the world is becoming increasingly more aggressive and added to that the rising costs and investment pressure, combined with ever higher material and energy prices, as well as high customer expectations with regard to delivery reliability. For a long time now, the issue has not "merely" been about being able to continuously monitor production quality. Rather, there is an increasing demand to be able to detect the causes of defects early on, so that material and time are not unnecessarily wasted.

Just how urgent this requirement is can be seen quite clearly in this profitability analysis example: a system for fine paper produces approximately 300,000 tons per year. The price for a ton of paper of this quality is around € 700. Typical losses during paper manufacturing, for the most part due to web breaks, are around 5% of total production - 15,000 t. Paper scrap can be recycled and reused in the production process. By doing this, the paper manufacturer saves around € 170 per ton. However, there is still a loss of € 530 per ton. This adds up to a total loss of close to € 8 million every year for a paper manufacturer of this size. This does not include penalties paid to end customers as a result of delivering a lower quality product.

This example clearly shows that the need to be able to analyze trouble spots in production is increasing. At the same time, production manufacturers must adjust to the high demands in the packaging industry for high-end packaging, the importance of which is steadily increasing. The smallest stripes can make the end product useless. This increases the number of returns. Moreover, manufacturers are required to extend their quality inspection to include every step in the production chain, including the coating lines.

Integrating a web inspection system in combination with a web break monitoring system has proven to reduce the number of web breaks by 30% to 70%. Customer returns can be lowered by 80%. What’s more, machine capacity increases as well. When

*Authors’ references:
1. ISRA VISION PARSYTEC
Corresponding author: Christoph Wiericks. Auf der Hüls183, 52068 Aachen, Germany.
Phone: +49-241-9696-480 – e-mail: cwiericks@isra-parsytec.com
manufacturing tissue paper, for example, this can equate to an increase in net production by up to 15%. The same applies to coated papers, because the converting process often represents a bottleneck in the production chain. Making use of an integrated solution that combines a WIS and WBM has proven to be the fastest possible return on an investment. With this technology, equipment operators receive detailed information about any troubles that may occur up to six hours in advance, giving them the chance to react in time. Below are descriptions of the web inspection process, of web break monitoring and also of how they can be linked to form an integrated system.

**METHODS**

Generally, we should distinguish between paper defects that decrease overall quality and those defects that may interrupt production or result in a machine shutdown. The paper quality depends on several visual factors. Not only may a defect interfere with the appearance of the end product, but also may reduce the expected benefits of the product. Even the most minute doctor streaks on coated papers are often not even visible at first glance, but appear clearly during printing. For process inspection and quality assurance, typical systems are used for automatic web inspection (WIS) along the entire surface. For the majority of end users, the ability to demonstrate inspected and recorded paper quality is an absolutely essential requirement.

Defects such as non-homogeneous structures or holes, dirt or wrinkles lead to production losses in almost every processing step, such as coating or printing. Even more important and significant for the direct paper production is the influence of discontinuities in the paper web. Small defects in the middle of the web do not typically result in bringing production to a total halt. Exceptions are: getting caught in the cylinders and ripping. More than 50% of paper machine downtimes are caused though, by holes and rips at the edge area of the web. These kinds of production relevant defects are recorded with the use of web break monitoring sensors.

**Web Inspection Systems - WIS**

An inspection system is used to determine the actual status and to compare it with the desired target status. Where web inspection is concerned, it is especially critical to be able to detect unwanted defects. WIS detect and classify defects, such as different types of holes, spots (water, oil, ...), inclusions, foreign particles or edge defects that can impact the quality of the manufactured product. 100% of all quality relevant defects are reliably detected and classified with web inspection systems. Even defects that are difficult to detect can be reliably identified with state-of-the-art WIS.

The inspection systems consist of tried and tested high quality standard components. Because of the way they are constructed, these systems are highly customizable to match the needs of the customer. What is key to the systems’ performance is their ability to inspect in real time, their rugged design, and the reliability of their results.

State-of-the-art inspection systems are often equipped with high-resolution 4096 pixel or even 8192 pixel camera technology that are capable of scanning the surface with up to 200000 scans per second. The consequence: maximum resolution for highest processing speeds. They can be installed both, above the web as well as below it. Combined with the very latest in illumination technology based on high power LEDs and luminosity levels of 120000 candelas and higher per cm², web widths of 10 meters and more can be inspected. Brilliant surface images are recorded and processed immediately in real time by hybrid, distributed multiprocessor systems - quality information that can be used immediately is available in no time at all. This technology is made possible based on programmable electronic modules, which are referred to as “field programmable gate arrays” (FGPA). The ability to realize even the most complex algorithms, such as two and three-dimensional filters, using them even with maximum quantities of data, is absolutely no problem. In this manner it is possible to reliably detect and classify even defects with extremely low contrast down to the 50 micrometer range, such as the minutest doctor streaks with precise reproducibility - a key benefit of the inspection systems.

The systems inspect, analyze and classify missing spots completely automatically. Defects are logged by the inspections systems and are documented in defect statistics, on defect cards and on defect images. Reliable, reproducible and clear inspection results are achieved even under the most critical conditions.

Defect detection and classification assures that the most stringent quality requirements are guaranteed. To be emphasized, here in particular is the easy-to-use defect classification module. It is the ideal addition to the inspection. The multi-level classifier guarantees high quality defect classification and makes use of 800 different mathematical attributes with which to describe a defect. The classifier can be trained efficiently. You only need 15 minutes to add an additional defect class. Most of the defects are already preset. The operator receives information that has been classified in the form of indirect alarms, statistical evaluations and analyses. A new operator interface presents all of the results in a clearly arranged form.

The latest inspection systems consist of a “smart frame”. Here, computer technology and cameras are installed in a compact frame, which offers many benefits. Not only does this provide easy access to both the cameras and the PCs for maintenance purposes, but it also reduces the installation effort needed with regard to the electronics and mechanics, not to mention the reduced space requirements - no control cabinet is needed. The systems can be networked with an Ethernet connection and, as such, can be accessed virtually from anywhere in the world. So, the user can operate and observe inspection systems installed at various locations from a central control center via the Internet. Production managers have the
ability to access equipment remotely and obtain an overview of the production quality directly beyond plant gates and country borders.

The inspection systems, on their own, already play an essential role in maximizing profits. However, based on the conditions defined by increased global competitive pressure, inspection alone is not enough to make the processes more efficient and to systematically optimize production. Having knowledge that high-quality products were produced can only be the first step.

**Web Break Monitoring - WBM**

Automated web product manufacturing processes in the paper industry can only be accurately optimized if meaningful information about any production defects is available at a very early stage. Web break monitoring has proven to be very successful in paper manufacturing applications. It allows the ability to draw conclusions about the causes of defects by taking on the task of recording defects such as web breaks and other critical occurrences, and preparing a video analysis of them. Selected process relevant critical areas are monitored, recorded and analyzed by sensors. WBM sensors automatically set off an alarm in the form of signals or images if trouble spots are found, or if predefined limits or parameters are exceeded. It is even possible - with the relevant analysis algorithms - to draw targeted conclusions relating to processes and the causes of defects.

In the past, web break monitoring systems of this kind were relatively expensive and even difficult to integrate into production environments. This is not the case for the IntelliCams, the web break sensors, which can be linked to web inspection systems (WIS).

WBM sensors can be installed at all critical positions throughout the entire production system. Among these positions along the process chain are wire & trim, pick-up, open draw, press-to-dryer, predryer, dryer, size press and calender & reeler. When several sensors are used, a higher information density is achieved, which can even lead to a partial inspection of the surface. The sensors are installed at different processing steps along the paper machine, which allows the development of defects to be analyzed with a greater degree of accuracy. On average, 16 to 20 WBM sensors are used in a system.

For the intelligent WBM described here, the corresponding IntelliCam HD- or HD+ camera sensors, LED illumination and embedded PC are combined in a rugged stainless steel enclosure. The intelligence is already integrated in the sensor, which can be installed directly into the machine with ease. The advantage, here, is that only relevant information needs to be transferred to the overall system, not all the data as was necessary in the past. The sensors make the essential detailed information about the results available at the signal output. They perform their tasks reliably via a Gigabit Ethernet (GigE) connection even at distances far from the evaluation computer. The system operator has the added benefit that only very few components need to be in stock, because everything is already integrated into the sensor. The high intensity LEDs have a typical life cycle of ten years or more.

The IntelliCam sensors are optimized for conditions in the most difficult environments. The sensors are designed for protection class IP65. No special safety precautions need to be taken because they are supplied with 48 V DC low voltage. The view panel is cleaned automatically with a rinse water unit and wipers. This applies not only to the high-quality lenses, but also to the lighting fixtures. This guarantees that the images are always clear. These rules get rid of any dirt on the viewing area. The LAN network-capable sensors can be combined and linked. The CMOS cameras, with a resolution of up to 2048 x 1088 pixels, allow for flexible use. It is also possible to use them as high-speed cameras with up to 400 images per second.

![Image 1. Typical web breaks that occur in the paper production process](image1)  
![Image 2. Web Break Monitoring (WBM) with IntelliCam even in roughest production environment, e. g. tissue production](image2)

**Linking the web inspection systems with the web break monitoring system**

In the past, camera systems were used in the paper manufacturing industry in two clearly separated areas of application - WIS or WBM. Suppliers either offered WBM or WIS. The corresponding software algorithms had not yet been developed to the extent to allow both systems to be combined. WBM systems were only able to detect very large defects and defect tracking within the process was not possible at all.

Today, though, paper manufacturers need a complete productivity solution for the entire manufacturing process chain. The ability to make fast and targeted decisions at each level in the company that will allow an increase in production efficiency definitely requires access to all relevant information and the ability to assess it reliably. The goal is to be able to find the right answers to questions having to do with maximizing profits and optimizing processes.

This is the reason for the need to link WBM and WIS. All information...
Typically, a web inspection system is installed at the end of a production machine to allow it to monitor the produced quality. The WIS records and categorizes all paper defects that are relevant to quality. The corresponding video sequences that relate to the defects detected by WIS are displayed synchronously by the IntelliCam sensors, despite the fact that the paper machine runs at different processing speeds. This makes video sequences available, in addition to the defects and classification information provided by the WIS. The result: paper manufacturers are able to draw accurate conclusions about the origin point.

is gathered on a server. The WBM is responsible for recording events. The preliminary information from the WBM is transferred to the WIS.

The inspection system analyzes the web based on the information supplied exactly at the defined positions. In the process, all information is available from one single operator station. Another separate operator station for the web breaking monitoring system is no longer required. As such, there is one platform for all monitoring tasks: inspection, analysis, web breaks and events. With the platform, the manufacturer has the same number of functions, but can save on equipment costs and installation effort.
All of this is possible, even at different processing speeds along the machine and despite different sensor viewing ranges and the variety of camera resolutions. This is a key advantage, because processing speeds can vary at the different paper machine stations. In our example relating to tissue manufacturing, this can be up to 15% in some cases because of the crepe factor. What’s more, depending on where they are put to use, the WBM sensors record either the entire web or only a partial section, which will result in different camera resolutions.

The ability to link WIS and WBM information makes it possible for the first time to understand much faster where a critical defect occurred or why it occurred. The cause of problems is identified, the machine is better “understood”. The results are not only a conventional analysis of the events, for example breaks, but rather the system provides information directly online about where the defect originated and its cause. The ability to introduce measures immediately to rectify the defects makes it possible to initiate preventive measures that will improve production overall. Motivated production managers are therefore given the opportunity to significantly improve production efficiency.

Mentors that support making economic decisions

Using a modular set of efficient tools for web inspection systems allows the manufacturer to systematically optimize the entire production process even further. Tools that have proven their value in countless practical applications assist in decisions that will lead to increased efficiency. They support the paper manufacturer in efforts to optimize production. Among these “experts” are, for example, the modules In-line Dirt Count, Defect Trend, Unwind Control, Defect Tracking, Slitting Preview and Customer Roll Reports. The modules offer economic decision-making support for optimizing production in paper manufacturing. They allow the user to decide for himself which combination of mentors he wants to use as the one most suitable for his application. Even as stand-alone modules, these tools offer quite a few benefits. It is possible to expand them step-by-step.

The benefits can be used for any type of paper or cardboard in a variety of grammage options, regardless of whether it is colored, painted or coated.

The Web Break Monitoring System can also be upgraded by adding additional valuable options. They offer even more benefits. The Trim Squirt Analysis module gives the user a signal if there is too much dirt in the water nozzle at the front of the paper machine. The signal is issued once a level is reached at which clumps might fall onto the web, which would create web breaks. The Release Point Analysis Module monitors the lifting point at which the paper traverses from one roll to the next. If the lifting point is no longer in a certain tolerance range, the operator is given a signal. This can help to prevent rips in the paper. The Tail Threading Analysis module assures that paper production can start up quickly and that its start is correctly predicted. Paper web threading is a complicated and long drawn-out process, which is typically performed with the help of a narrow ribbon or a tail. The module monitors this process at the most critical points. Another module, the Edge Analysis module, is responsible for assuring that the edge cutting process is carried out with the help of a water jet under the best possible conditions. This is also a critical point where there is otherwise the risk of edge breaks.

RESULTS AND DISCUSSION

It has been successfully shown that the use of WIS or WBM is beneficial to paper manufacturers. By integrating other optional tools, it is possible to optimize the production process even further. However, paper manufacturers are not ideally prepared for all of the demands they will face in the future until they can link WIS and WBM into a single system based on state-of-the-art hardware and software technology. This complete, highly integrated productivity solution for the entire chain of the manufacturing processes, correctly answers several questions that relate to maximizing profits and optimizing the processes as a whole. Some of the leading paper manufacturers in Asia, America and Europe have already realized the benefits that could be achieved. As an example, Bohui Paper placed an order for the integrated solution consisting of a web inspection system (WIS) and the web break analysis system (WBM) for one of the world’s largest cardboard machines. This system provides the Chinese company with an answer to increasingly higher demands for higher quality cardboard packaging. Web breaks are analyzed in the system and strategies are developed to prevent them. The integrated solution will go into operation in the summer of 2012. [2]