Improving papermaking & coating efficiency with web inspection cameras

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Abstract

Paper breaks and various defects are an efficiency robbing reality on all types of paper machines, coaters and downstream converting operations. Eliminating breaks and paper defects has become more and more important with the increasing speed and operating complexities of today's paper, board & tissue machines. Papertech's TotalVision™ now offers papermakers a single high speed camera based platform allowing all types of defects (holes, slime, oil, etc.) at the reel to be seamlessly analyzed to their root cause right to the wet-end. This eliminates operator guesswork and rapidly allows breaks and defects to be eliminated.

The system is based on fully digital high speed & resolution cameras from the winder to the wet-end that are combined into a single web inspection and web monitoring platform, with a single user interface, able to automatically pinpoint and analyze all types of process disturbances. It uses the latest GigE-Vision® based digital cameras, GigE digital video transmission and intuitive digital image processing software, to see at high machine speeds the event and find its origin. The cameras continuously monitor, in real-time, all of the critical locations from the wet-end to the dry-end of the paper machine resulting in total 100% sheet analysis.

In addition to this many important innovations have been made to ensure cameras can survive and provide good image quality without operator involvement. For example, EverClean now makes it possible to have cameras stay clean indefinitely even in the dirtiest applications. This combined with powerful papermaking designed lighting, ensures good image qualify is achieved ensuring the overall system maintains its performance month after month.

These systems have now been proven on all types of paper machines, coaters, tissue machines and various converting operations. The total vision single platform provides a truly powerful, and easy to use, troubleshooting and papermaking optimization tool that has been shown to yield a less than six (6) month payback.

KEYWORDS: Paper & tissue machines, coaters, breaks, web inspection, machine monitoring, defect detection, break recording, presses, dryers, finishing, CCD cameras, GigE, runnability, efficiency, troubleshooting, payback.

Introduction

Break or event recording cameras have now been used on all types of paper, board and tissue machines for over a decade. During this time camera, lighting and computer technology, to capture and analyze all types of events causing runnability issues, has evolved at a rapid pace fuelled by the need by papermakers to more extensively analyze their runnability issues.

Break or event recording camera systems, which are now commonly called Web Monitoring Systems or WMS, have become a standard means of solving and eliminating even the most difficult paper machine runnability issues. It is estimated that there are now over 1400 WMS systems around the world with Europe and North America representing around 80% of the installed base.

Over the last five years some 100 to 125 WMS systems have been sold each year, and are now being used in over 30 countries. The highest saturation of WMS systems is in Northern Europe, which resulted from initial development of this technology beginning there in the mid nineties together with the demand to operate machines at highest possible efficiency and production levels.

WMS systems have over the last decade become more intuitive allowing operators to quickly and efficiently find the root cause, or origin, of their break causing defect or other quality issue. The cameras have become "smart" with full image recognition capabilities allowing them to see and alarm for any change in the sheet. In other words WMS cameras are now functioning the same way as web inspection systems (WIS) located at the reel. This together with better image quality, more images per second, has allowed all types of machines, including small ones, to justify the investment of automated camera based web monitoring technology. Figure 1 shows some examples of WMS captured events.
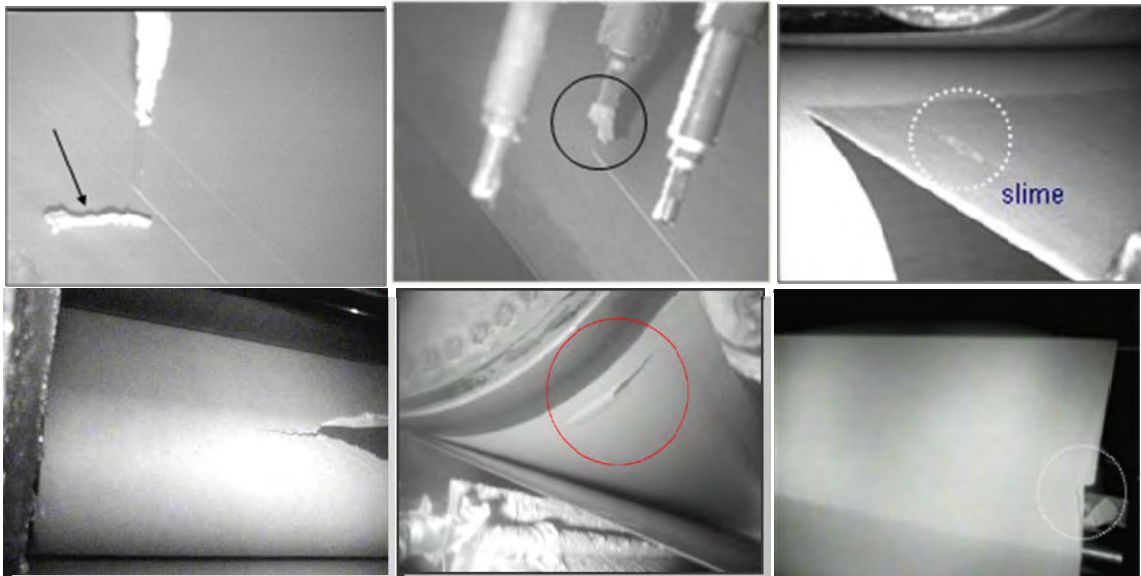

Figure 1: Shows some example events captured by high speed cameras that are going to cause, or have caused, a break. Most commonly problems occur in the forming and press section, and in many cases are originating from poor trimming on the wire.

Web Monitoring Technology (WMS) Past and Present

In the beginning of the nineties, major advancements were made in CCD (charge coupled device) camera technology, which resulted in faster shutter speeds, improved image quality and higher resolution "Super" VHS format analog VCR's. The outcome of such an improved break recording system was reported by a Mid-Western paper mill *(1)*, and demonstrated the potential that these systems offered in solving the root cause for unknown breaks.

Such an automated analog (VCR based) event capturing system was also installed on the *UPM-Kymmene*, Kaukas mill's off-machine coater in 1993. In 1994 at the Tappi Coating Conference *(2),* the mill reported a major speed increase.

Over the next five years many automated basic software based WMS systems were installed, allowing for easier, faster and more reliable means of storing and reviewing breaks. Many of these developments were reported at the Tappsa African Pulp and Paper Week Conference in 2002 *(3)*.

The next evolution has taken place in the last 3 years with the advancements in digital image technology that allows higher resolution and higher speed images to be generated than the old television broadcast standard (NTSC in North America, PAL in Europe and elsewhere). Analog broadcasting is now rapidly disappearing particularly in the Western countries. In the next 5 years it will be replaced by digital TV or DTV (see www.dtv.gov) or HDTV as it is commonly called and noted on TV monitors. Just like DTV is providing consumers with higher definition images, industrial digital cameras are providing papermakers with a much higher image quality (see figure 2) and much higher image speed going from the past 50 or 60 images/second to as high as 1000. High definition digital cameras with its many extra benefits to solving paper machine issues will now rapidly gain momentum *(4)*.
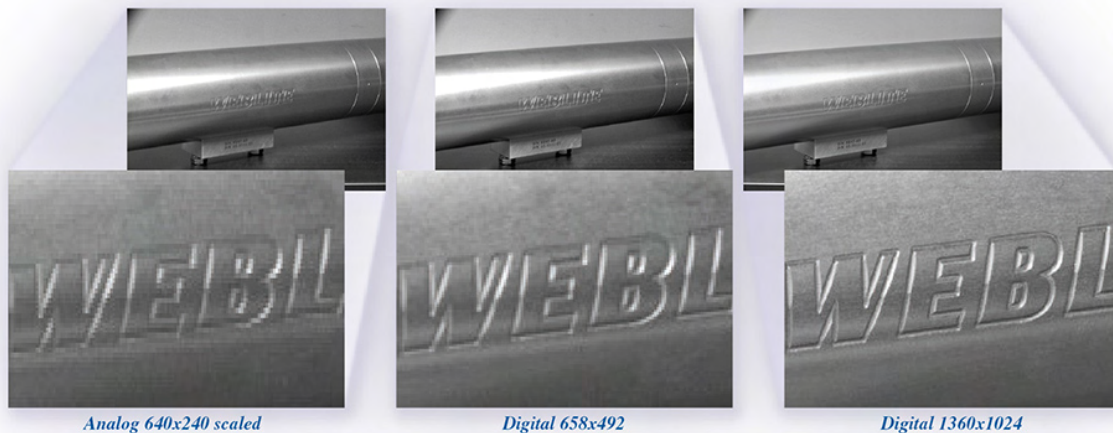

Analog 640x240 scaled   Digital 658x492   Digital 1360x1024

Figure 2:
Shows the image difference between analog (TV broadcast standard) on the left
compared to higher resolution, and higher speed, digital cameras.

Over the last five years various digital formats have been evolving. The three primary ones for industrial applications are: FireWire, CameraLink, and GigE-Vision. Of these the GigE-Vision® standard has become the preferred choice for several important reasons:

- It is a worldwide standard, from the Automated Imaging Association (AIA), is an interface for high-performance machine vision cameras that is widely supported in the industrial imaging industry.
- It is based on the well known standard Ethernet and has a high data rate of 1000Mbps.
- Offers the largest selection of industrial cameras.
- Most economical due to lower cable costs, lower camera costs, lower interface costs, lowest development costs.
- Longest direct transmission distance of 100 meters (330 ft) using standard CAT UTP cable

Based on this it is expected that paper machine WMS systems will be standardized on GigE fully digital image handling.

Must Have Features

Today's WMS systems are able to provide a paper machine, or converting line, a host of powerful features that will allow the root cause of the efficiency robbing issue to be solved. When considering a camera system today the following should be the "must have" list of capabilities:

1. **Digital Cameras:** high sensitivity, uncompressed high resolution, high image speed, noise free, and ability to "plug and play" accept different cameras including colour.
2. **No weak links:** cameras that stay clean even in the dirtiest locations, effective and efficient lighting, robust mounting, cabling that minimizes noise, industrial class computers and reliable software.
3. **Operator friendly:** intuitive, complete and easy to operate software allowing operators to rapidly find the root cause of the break or defect problem.
4. **Instant download:** all event data can be immediately analyzed before re-threading, and breaks can be stored seconds apart without any loss of video information.
5. **Long video history:** sheet wet-end to dry-end transport time plus 2 minutes typical with the ability to extend to several hours for solving defect related problems.
6. **Non proprietary:** all system components including computers should be off-the-shelf, mill maintainable, allowing for easy upgrading and low cost ongoing maintenance.
7. **Full web inspection integration:** using the same WMS cameras the system has to have the capability also performing detailed web inspection (WIS) defect detection complete with reel map display and classification of defects into various papermaking categories. This reel to wet-end total vision integration provides a powerful platform to allow rapid dry-end defect to its root cause detection right to the wet-end complete with defect image transfer capabilities and accurate same piece of paper synchronization.
8. **Millwide information system (MIS) intergarion:** provides event summary statistics, highlights problem areas, automatic tracking of downtime, etc. and is typically today performed most effectively using OPC data linking.

All of the above is now possible with the latest WMS systems and offers such an improvement in performance that it can be justified to either partially or fully upgrade previous generation WMS

and WIS systems that might only be two years old. Figure 3 shows a typical synchronized break event and how the cameras and lights look placed in the press section.
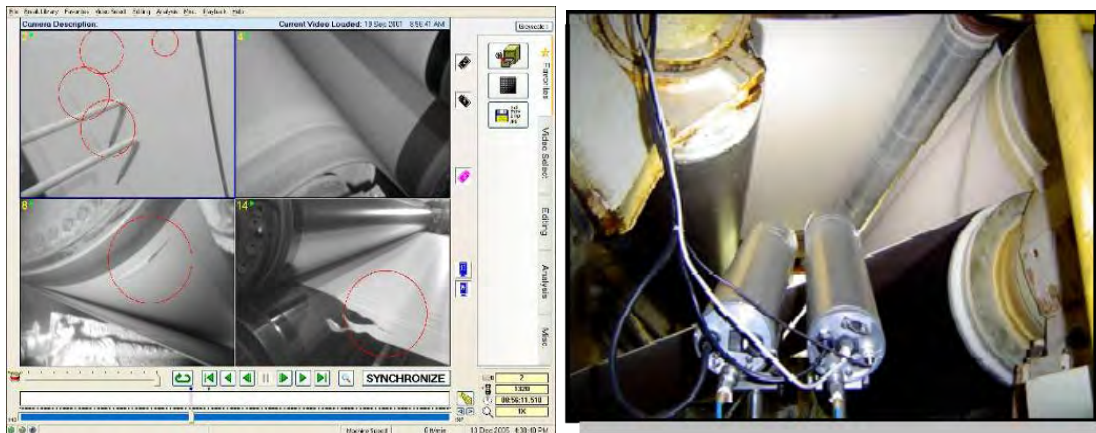

Figure 3: The left side WMS computer screen image shows a same piece of paper synchronized event with multiple slime holes on the wire ultimately causing a break at the calender. The right hand side shows a typical camera and light set-up viewing an open draw in a press section.

Figure 4 provides an example of a WMS system based on fully digital camera platform and using either UTP (CAT) or fiber cabling, combined with digital real-time image displays.
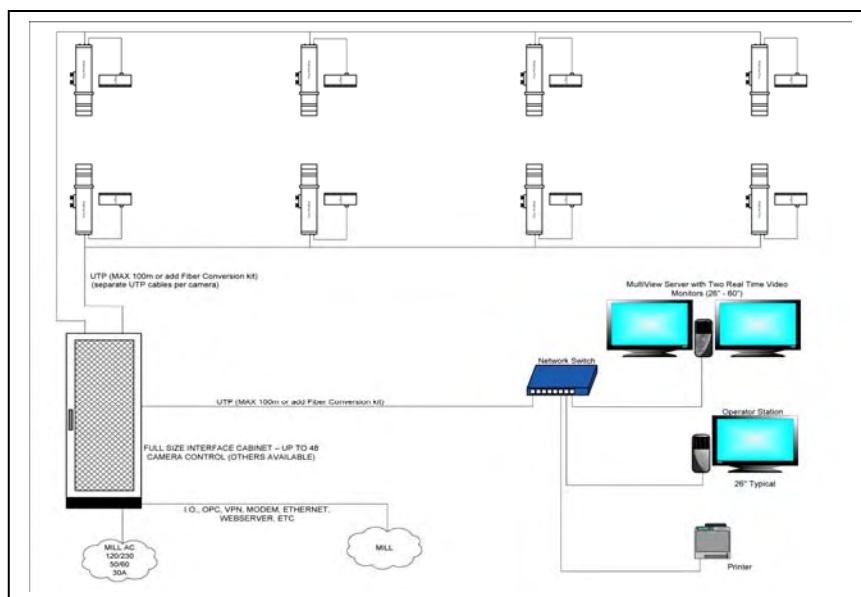

Figure 4: A typical fully digital WMS camera system layout drawing. Automated digital break recording systems are designed to maximize the visibility and results on all types of paper machines and coaters to prevent and eliminate breaks as well as holes and other quality defects. The interface cabinet houses the standard PC computers, digital image processing and storage components and is typically located in an electrical room. The operator control station provides full operator access to the camera images and provides advanced software features to rapidly find the root cause of the event (break). Live real-time digital images are provided allowing all cameras to be rapidly viewed by the operators.

Camera applications for web monitoring (WMS and web inspection (WIS)

Cameras and light housing technology is available today that can stay clean for extended periods *(5)*, can withstand the highest temperatures, and have a small enough size and mounting flexibility, to fit into nearly any position on a paper machine, pulp machine, coater, supercalender, winder, and a multitude of tissue converting lines. Figure 5 shows where cameras are typically located on a conventional paper machine. Figure 6 shows how both WMS and WIS cameras provide a means of fully monitoring the papermaking process through the winders to various converting operations.

The trim squirt application is very useful in ensuring that trim nozzle build-up, wear and plugging is not effecting their operation and causing breaks. In many cases poor trimming can account for as much as half of all the breaks, and eliminating this problem becomes very important. Fortunately the latest trimming systems, such as SuperTrim, are now able to eliminate trim related problems.

In the press section the most common locations are the pick-up, center roll and last press. All open draws should be monitored. Viewing the sheet in the first dryer section is also important and particularly useful with unfelted uno-runs as this allows full cross direction viewing of the sheet. Coaters and size presses are always camera equipped due to their typically high break frequency. Calenders and the reel, for turn-ups, can also be problem areas. Winders can be equipped as well as other off-machine operations, the most important one being off-machine coaters.
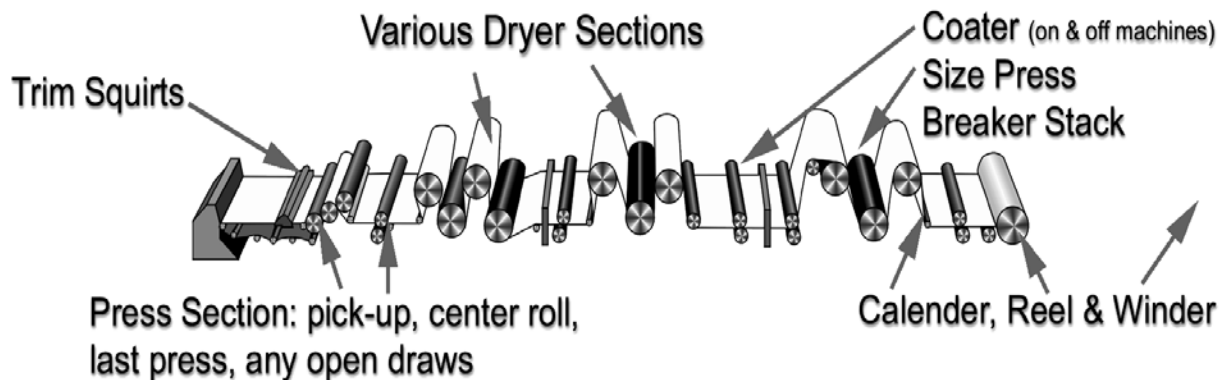

Figure 5:
Using self cleaning cameras, with waterproof and high temperature rating, they can be located in all break sensitive locations with minimal concern over image quality and maintenance issues. The most common locations on conventional paper machines producing newsprint and fine papers are: trim squirts, pick-up, press section open draws, first dryer section, coater exit, size press exit, calender exit, reel for turnups and winder for edge issues and inspection.

Single camera platform

Single camera platform
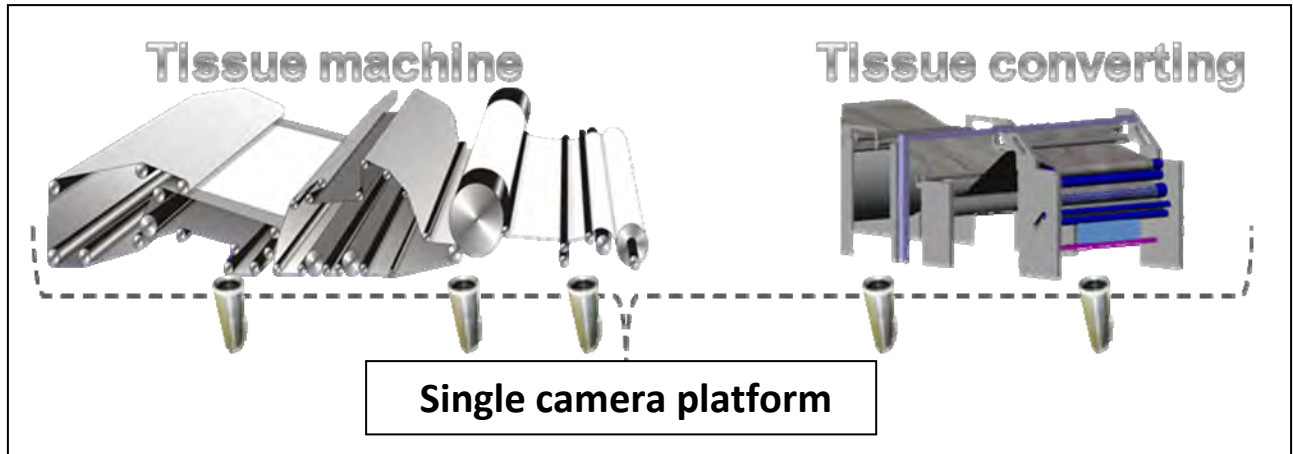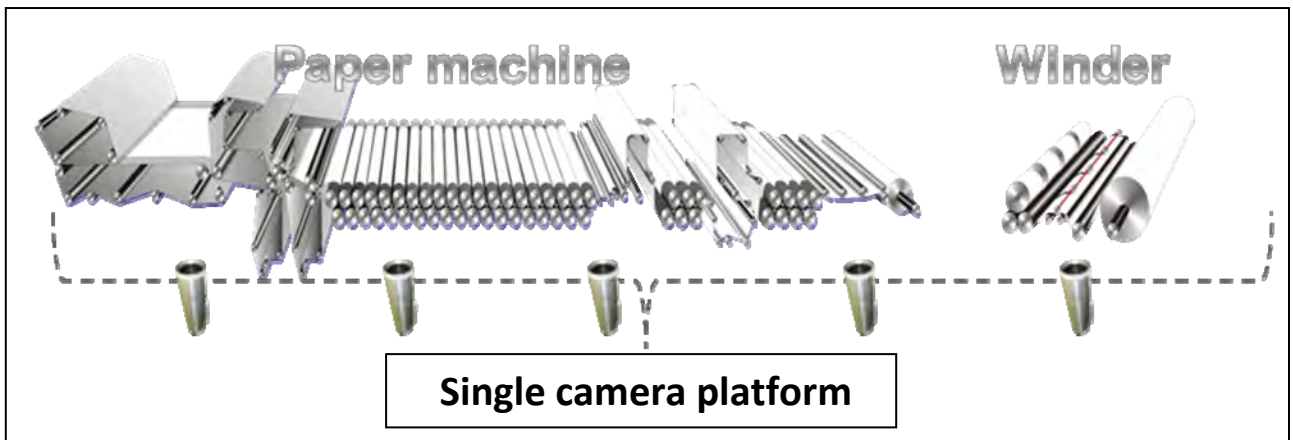
Shows how both web monitoring (WMS) and web inspection (WIS) cameras are able to total vision integrate the papermaking process all the way through to the converting operations allowing a fully automated visual means of finding production bottle-necks and their root cause sources.

Results

Breaks are typically classified as coming from either known or unknown sources. Breaks coming from known sources can usually be eliminated, but it is for the unknown breaks that a WMS system is needed. Also it should be noted that experience has proven that many believed to be known sources of breaks have actually been found with cameras to be originating from another source, ie. they actually were unknown.

A further WMS result is that preventive measures can be taken prior to a break occurring. This can be achieved today with automatic triggering of cameras as soon as they see a change in the sheet from a normal condition. Essentially all WMS cameras today perform in the same way as web inspection cameras, and can be set-up to trigger on all types changes in the sheet and surrounding conditions. Such break preventive examples are problems occurring on trim squirts, felts, sheet flutter, sheet tension, vibration and various condensation and operator error.

With now hundreds of WMS systems operating on all types of paper, board, pulp and tissue machines, it has become clear that this technology provides an effective means of solving breaks and provides a rapid return on investment (often less than 6 months). With a sufficient number of

cameras correctly placed, a complete picture of the event can be achieved from any part of the papermaking process.

The elimination of all unknown breaks is a function of several variables such as: type of camera system, type of break, similarity of breaks, number of cameras, camera locations and user capabilities and commitment. It should be noted that with the advancements that have now been made in WMS technology it has become much easier for operators to find the root causes of breaks and defects.

A further noteworthy WMS development is the opportunity to fully integrate web inspection (WIS) with it. For many years many WMS systems were set-up to receive a trigger signal from the WIS allowing same piece of paper synchronization of the hole or defect right to the wet-end cameras. Now these two systems are fully integrated allowing two-way communication between the two systems into what can be called a total vision solution. Now when a certain size hole, edge crack, surface defect is detected by the WIS, this image, with its exact time stamp, is sent to the WMS allowing operators to see the defect on the WMS screen together with all of the same piece of paper images all the way up to the wet-end. Similarly the WMS can send to the WIS images from certain defects further helping operators get to the root cause of quality disturbances. Figure 7 shows a fully WMS and WIS system operator station in a board mill in Sweden.

Figure 7:
Shows how a fully integrated, single platform, web monitoring (WMS) and web inspection (WIS) operator station that allows a defect to be automatically from the WIS to be transferred to the WMS system synchronized to the same piece of paper. This allows for a rapid and accurate means for the user to find the source of the defect and to eliminate it. A single keyboard and mouse is able to operate both systems.

Result examples

As noted earlier WMS systems have demonstrated the ability to eliminate unknown breaks and to provide a significant, typically 50% to 80%, reduction in breaks. This in most cases provides a less than six (6) month return on investment even on smaller lower production machines. Table 8 lists various users and the results they have achieved.

Web monitoring system user	% Unknown Break Reduction, Cull Reduction	% Speedup and Payback
Weyerhaeuser, Longview, USA	50% less culls	14% speed-up
Australian Paper, Maryvale, Australia		< 3 month payback
Sappi, Alfeld, Germany	28% less overall breaks	Best investment in 2 years
Georgia-Pacific, Halsey, USA	20% less breaks	+400-500 fpm (+120-150m/min)
Rondo-Ganahl, Austria	15% less breaks	8% speed-up and new production record
Aylesford Newsprint, UK	58% less breaks	<3 month payback
Stora Enso, Anjala, Finland	37% less breaks	10 less breaks/month
Rand Whitney, USA	66% reduction in break lost time/day	<2.2 month payback
US Gypsum, California, USA	68% less breaks	

Table 8:
Web monitoring systems (WMS) are able to provide papermakers a major reduction in breaks thus increasing machine efficiency, eliminating bottlenecks, and allowing in some cases an increase in speed when the machine speed has been "break limited".

The following provides examples of WMS (+ WIS) results based on the grade produced.

Newsprint and fine papers

Fast running newsprint and fine paper machines generally experience breaks in the wet-end, as well as at size press, coater and other complex location. Generally 10 to 20 cameras are required to see all critical locations.

A West coast Canada newsprint producer installed an eight (8) camera WMS system integrated with the web inspection system (WIS) and was within the month of the installation able to dramatically reduce the lost time hours as shown in table 9.
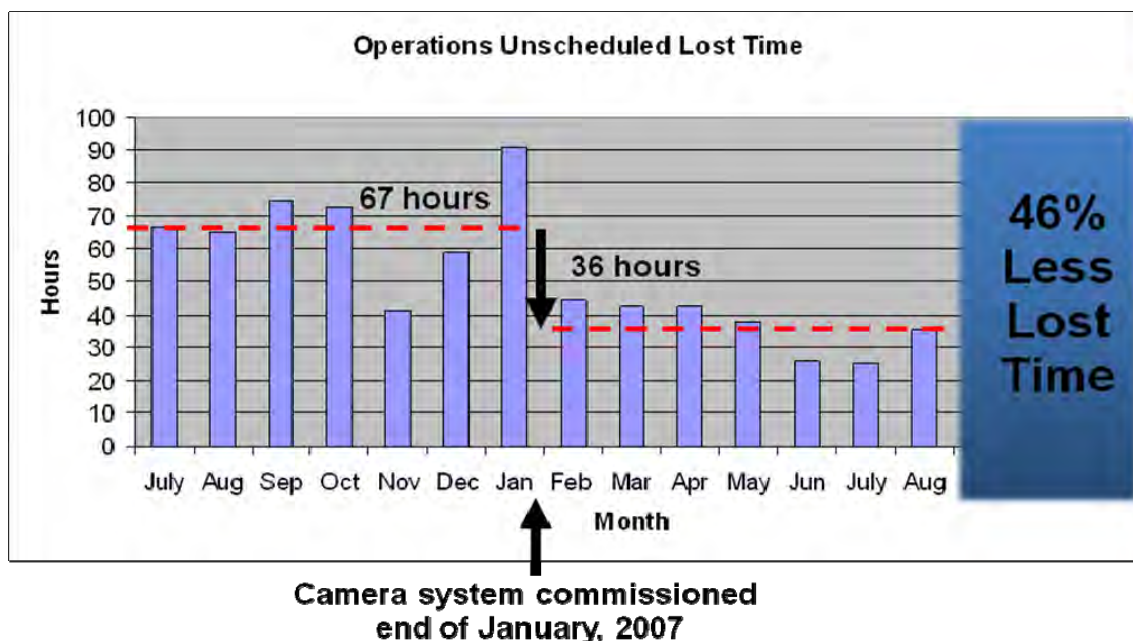
Camera system commissioned
end of January, 2007

Table 9:
Shows how a newsprint machine following the WMS camera system installation that was fully integrated with the existing web inspection system (WIS) was able to immediately reduce break and defect related lost hours following the start-up.

Pulp

Pulp machines operating at slow speeds generally have significantly fewer breaks then paper machines. In general the higher the percentage of shorter hardwood fiber pulp, the more breaks. Typically pulp machines experience 4 to 8 breaks per month. However, when breaks occur it can take from an hour to several hours until production can continue due the time it takes to clean the floatation dryer, etc. As a result each pulp break is very costly particularly if maximizing production is important and the machine is running at full drying capacity.

A Canadian pulp producer installed an 8 camera system on their 1500 t/day pulp machine positioning cameras on the wire, press, and inside the first dryer section. In the year preceding the WMS installation this machine had 80 breaks or 6 to 7 per month. The year after the camera system installation this dropped to 12 (1 per month), meaning a 85% reduction in breaks. The annual savings have been calculated at over $500,000., resulting in a payback of less than six months. With so few breaks this machine has became the highest efficiency pulp machine in North America. Figure 10 shows some example images from this pulp machine.
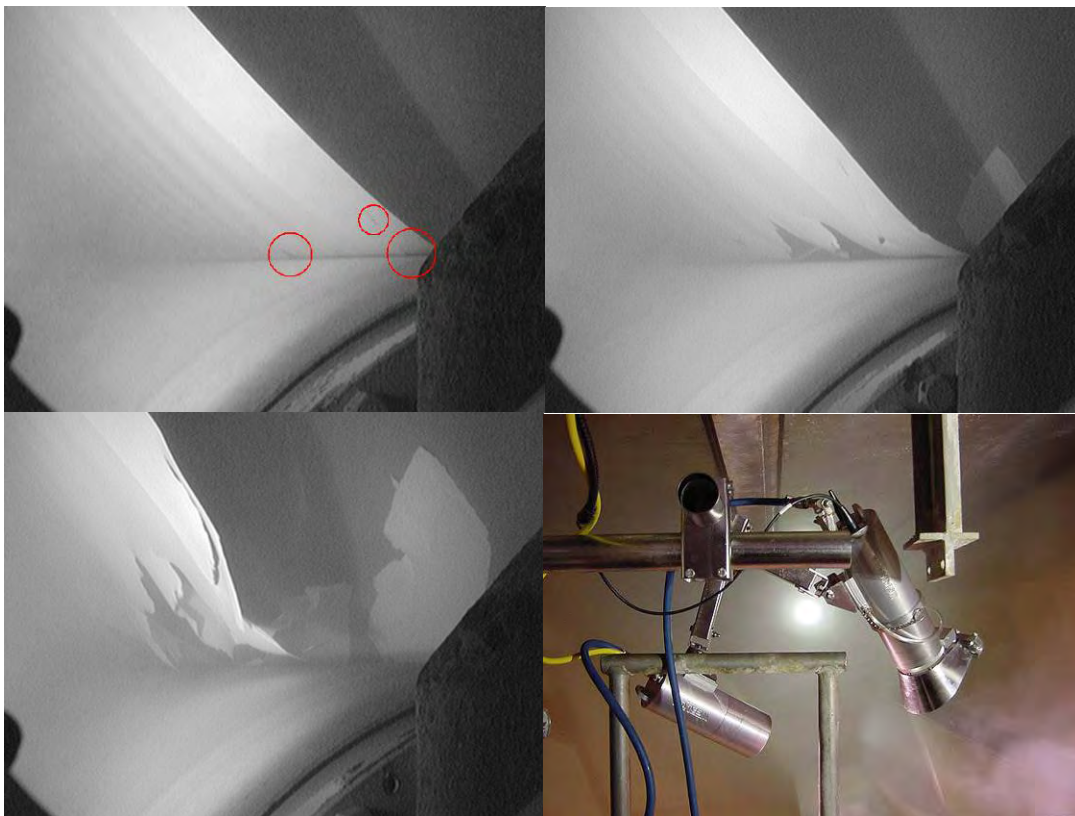
Figure 10:
Shows an example break on this pulp machine and how the cameras can see sufficiently well even under these often steamy conditions. This Canadian pulp machine was able to reduce their breaks from 6 to 7 per month to one (1) per month, resulting in the machine becoming the highest efficiency machine in North America.

Board

Board machines range from fast running linerboard and corrugating medium ones with fairly uncomplicated sheet runs, to ones producing heavy coated board operating at slow speed with a complicated and long paper run. The number of cameras can therefore range from 12 to over 30 to satisfy all of the possible event locations (see figure 11).

An example result to demonstrate that even small linerboard machines can justify a WMS system is a machine in Austria with a web width of 2150 mm (85"), operating at 800 m/min and producing 325 tons/day. This machine was break limited meaning they had to slow down the machine to reduce the number of breaks. The mill decided to install a large 16 camera system that included web inspection cameras integrated to the WMS. This allowed for complete machine visibility in all of the critical locations. Shortly after the start-up the papermakers were able to find out that a large percentage of their breaks were a result of trimming issues on the wire. They then purchased the latest trimming technology, were able to dramatically eliminate breaks and most importantly were able to speed up the machine. Ultimately they were able to speed up between 8% to 10%, and still experience 15% less breaks. This resulted in a less than 3 month payback (see figure 12).
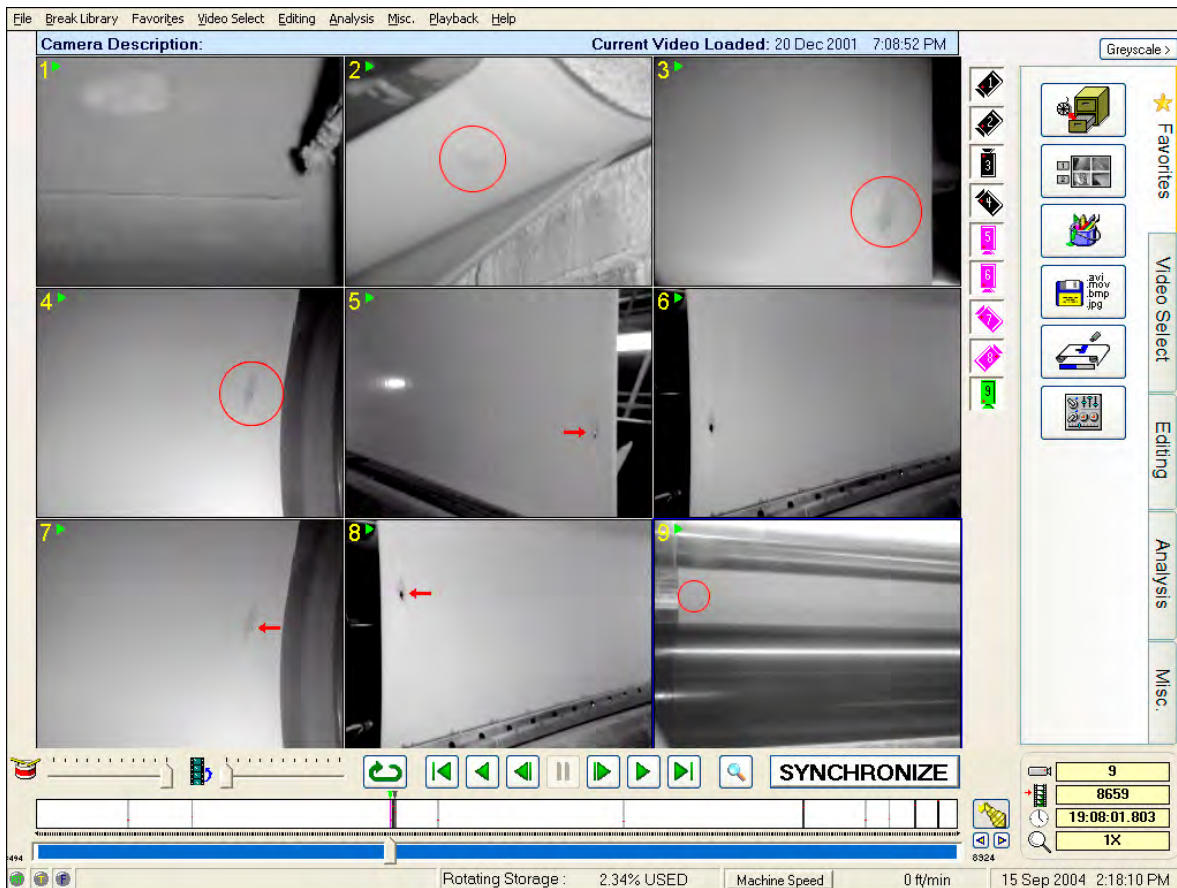
Figure 11:
Shows how a hole detected at the reel calender (image 9, bottom right) can be same piece of paper synchronized with the WMS system all the way to the forming section where it is found to be slime (image 1, top left). Of note is that this is a very long coated board machine that has 30 cameras to cover all of the critical locations, but this does not limit the ability of the cameras to automatically identify to the operator the root cause, or origin, of the problem.
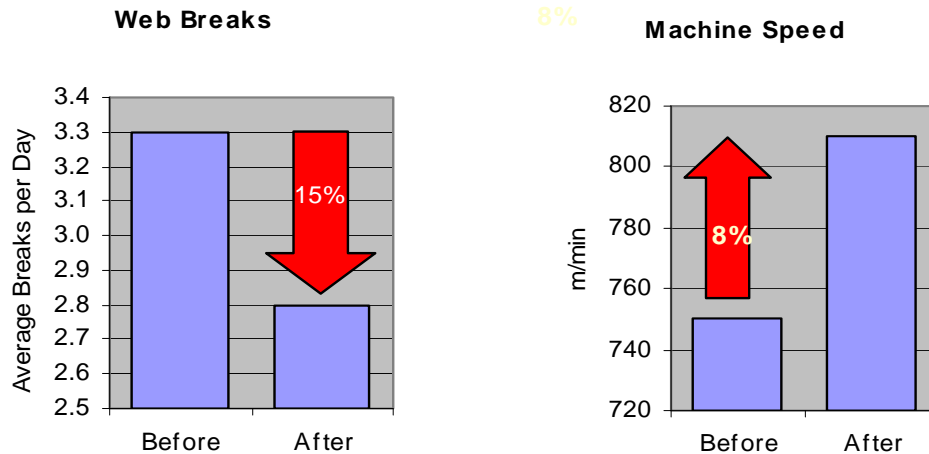
Figure 12: This small Austrian linerboard producer was able to with a 16 camera combined WMS and WIS system find the primary causes for their breaks, and thus speed up the machine and still reduce their breaks. In the past speeding up significantly increased their breaks. This resulted in a less than 3 month payback.

Tissue

Tissue is one of the more recent applications for WMS cameras, together with WIS, in not only the tissue machine but more importantly in the complex converting lines. Tissue machines can have many breaks (over 20/day), but most of them last no more than 5 minutes. These breaks can be identified with 4 to 6 cameras making the investment affordable, and payback rapid (see figure 13).

Figure 13:
Shows how a tissue machine "bubble" captured using colour WMS cameras results in a break at the creping blade and then the resulting problem at the reel.

On the tissue converting side the applications are diversified and require extensive WMS system customization to provide the needed visibility into small, complex locations. Much work has now been accomplished in this area in the last couple of years. With over 30 successful converting installations it is expected that WMS applications will become standard practice for all types of tissue and towel converters to ensure the required high operating efficiencies. Figure 14 provides an example tissue toilet paper roll log production problem and figure 15 how a hole generated on the tissue machine can create a break in converting line infeed.

Figure 14:
Tissue and towel converting is a new application area for WMS. Recent installations have demonstrated significant efficiency improvements in eliminating breaks and identifying their sources. The above shows, with 4 cameras, how the toilet paper log production is interrupted due to system not inserting the core in time.

Figure 15:
Shows a hole (left image), most likely generated on the tissue machine, causing a break on the infeed for the converting line (right image).

As discussed earlier basic dry contact triggering of the web monitoring system (WMS) by the web inspection system (WIS) when a certain type of defect is detected has been successfully implemented for years. This one way triggering has now been significantly enhanced with a two-way communication complete with defect image transfer and classification details. This integration provides the user with a pop-up instant image sent by the WIS to the WMS operator screen that automatically triggers a synchronized same piece of paper image series that finds the furthest wet-end camera that first saw this defect. Figure 16 shows a typical WMS plus WIS integrated operator station with dual displays giving the operator a total visibility of what all the cameras on the machine are seeing.

Figure 16:
Example of a combined WIS (left) and WMS (right) operator control station display set-up providing total visibility to all of the machine cameras synchronized to the same piece of paper. Full two-way software integration provides automatic image transfer via pop-ups, as well as defect classification information, and other important variables to help speed up solving the root cause.

Many of the combined systems have allowed papermakers to, as never before, solve the root cause of the defects (hole, edge crack, dirt, slime, etc.), making the marriage of these systems a must have. Figure 17 and 18 provide examples of how dry-end to wet-end camera integration can help the papermaker find the problem source.
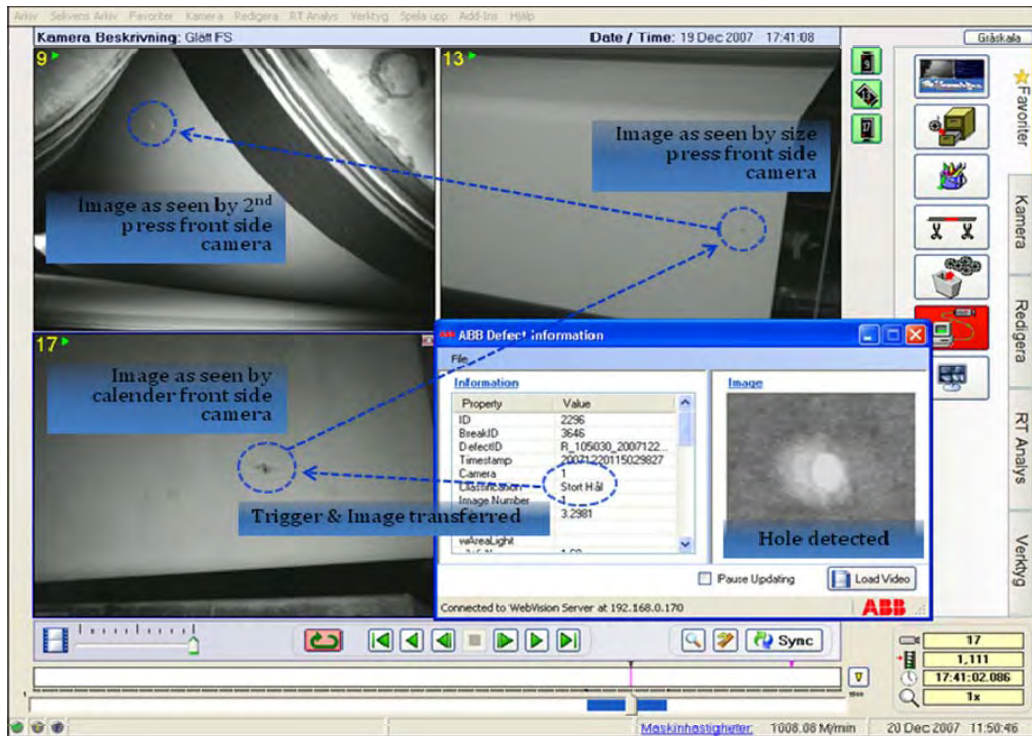
Figure 17: Shows how a combined WIS (left) and WMS (right) system. The WIS defect pop-up image synchronized with WMS shows that the defect was first seen by the 2nd press camera, which then concluded that the problem was debris on the wire.
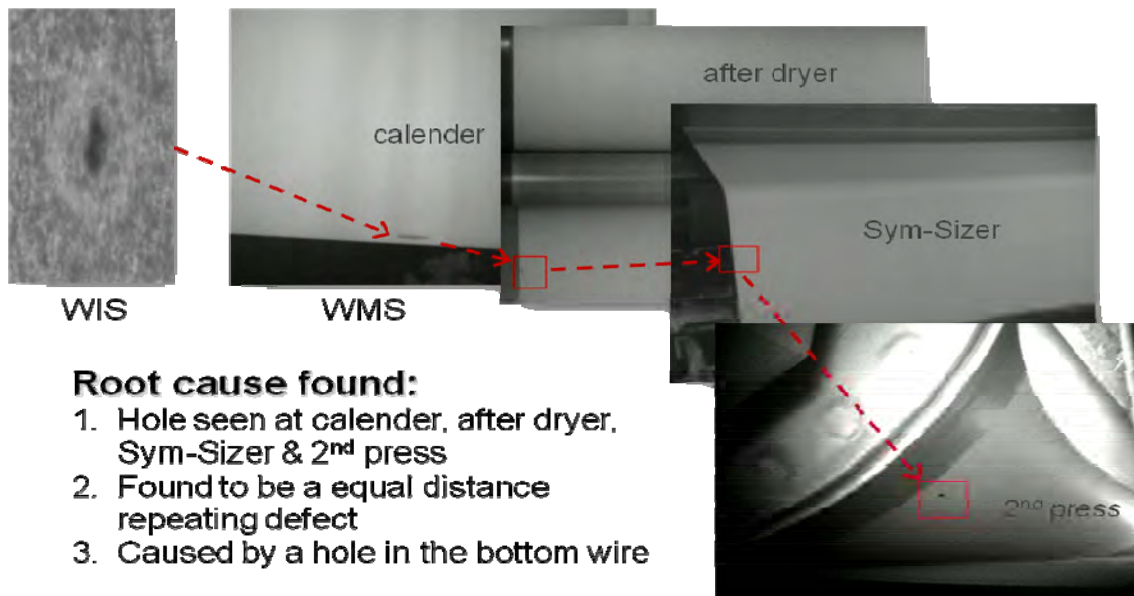

Figure 18: Another total WMS + WIS visibility example showing how the hole from the dry-end is analyzed all the way to the second press and found to be a hole in the wire. Both WMS and WIS should include frequency analysis features to find periodic problems originating from felts, wires, rolls, etc.

Conclusions

Web monitoring systems have been found to be effective in eliminating breaks and defects on all types of paper machines and converting operations from tissue to pulp. WMS technology over a 10 year period has now developed to a point where effective and reliable event capturing is possible, cameras are smart and perform continuous web inspection, and are fully integrated with all types of web inspection systems (WIS). The ideal WMS + WIS system is one that uses the same cameras, same processors and a single operating platform which simplifies the installation, makes maintenance easier, and offers the users the fastest and easiest way to achieve results.

One of the major improvements is fully digital cameras allowing much higher image resolution together with higher image speed, which all combined offers the papermaker many times more information to find the source of the break and defect.

In summary, automated fully digital WMS, combined with WIS, are today able to:

1. Automatically and in real-time monitor and record all critical locations on the paper machine, coater, winder, converting line, etc. using the latest fully digital high resolution and high speed cameras based on GigE-Vision.
2. Operate in easy to use PC Windows® based software allowing operators to fully view and manipulate all of the image information, and to receive automated early warnings from any camera that a operating change has occurred.
3. Allow videos to be viewed immediately following a trigger and to provide hours of video history to further analyze past upsets.
4. Fully integrate into a web inspection system (WIS) providing a two way communication that allows operators to easily analyze the defect with the WMS cameras all the way to the wet-end.
5. Allow environmentally enclosed, high resolution cameras to be placed in all of the critical locations, such as the wire and press section, dryer hood, coater, size press, calender, winder, etc without the need for periodic cleaning.
6. Provide a large database of the events that can be easily viewed, printed, tagged and compared to other breaks by type and also offer grade information, origin of break, etc.
7. Allow operators to be given early warning of a change, such as trim build-up, sheet flutter, and release angle so as to take preventive measures to prevent a break.
8. Interface to mill-wide systems for complete reporting using OPC and other high speed communications links.

With a WMS typical payback of less than six (6) months, it is expected that in the next five years, the use of this technology will continue to grow allowing papermakers to further improve their machine efficiency, production and product quality.

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