Digital Video for Faster, More Reliable Tissue Machine, Rewinder, and Packaging Line Operations

1.0 INTRODUCTION

"It is one of those systems that you ran without for 30 years, but now the operators wouldn't run the machine without it."

This paper presents[1] fourteen real-life case studies illustrating the use of digital video monitoring to:

- Identify the cause and methods to resolve sheet breaks on a tissue machine and rewinder. The system has identified the of the root cause of 90% of breaks, leading to a 20-50% reduction in breaks.
- Detect and reduce sheet defects on a tissue machine. Reduces breaks at the tissue machine and rewinder. Rewinder breaks are reduced by 50%.
- Improve turn-ups and diagnose core-handling problems on a tissue machine and rewinder resulting in fewer breaks.
- Reduce packaging line jams at roll conveyor, wrapper and case packer resulting in line efficiency improvements of 3-8%.
- Improve operating speeds on all machines. Results are often as high as a 7% increase in line speed.

Continuous digital video monitoring takes the mystery out of process failures and upsets. Cameras placed along the tissue machine, rewinder and packaging line record video continuously, 24-hours per day, at 60 pictures per second (50 pictures per second for PAL). When a break or line jam occurs, the system automatically shows the break or jam in slow motion. Precisely synchronized upstream pictures of the sheet allow operators to see where the root cause developed.

In addition, cameras function as machine vision sensors on the web. These cameras constantly monitor the web for defects such as holes, edge flips, take-off angle change, and trim squirt build up. These potential causes of web breaks can be detected and corrected before a sheet break occurs. Operators use the system to automatically see the same section of the web at all camera locations in the machine direction to determine the true origin of the defect. Engineers can apply solutions to stop these failures from reoccurring.

Digital video monitoring in tissue has some distinct challenges. The wet, corrosive and dusty environment requires careful design of camera enclosures and lights. The dusty nature of the views requires robust, configurable vision setup and control for the accurate, automatic detection of web defects. The rapid nature

"We live and die by productivity. The key is to increase machine speed and tonnage. The MTC Smart Advisor is giving us the confidence to run faster."

of the events (breaks, holes, turn-ups, etc.) necessitates the ability to handle gigabytes of video processing in a short time window while continuously recording. Finally, given the above challenges, the need for experienced tissue application engineers to place cameras and lights becomes obvious.

2.0 FUNCTIONS OF A DIGITAL VIDEO MONITORING SYSTEM

There are two distinct functions of a digital video monitoring system that provide value to tissue makers. First, a sheet break management system records, stores and replays digital video showing sheet breaks and the related upstream events that reveal the root cause and progression of defects that cause sheet breaks. Secondly, a real time web inspection system digitally analyzes video signals to detect sheet and process anomalies. These anomalies are then brought to the attention of operators, often before they cause sheet breaks.

2.1 Function: Sheet Break Analysis

When sheet breaks do occur, it is important to diagnose the cause so that they can be prevented from happening again. The digital video analysis system captures the sheet break while simultaneously searching for and correlating the most probable defects that are the origin of the break. This information allows papermakers to identify and correct the problem so that repeat breaks with the same root cause do not occur.

Sheet breaks are a costly problem for all papermakers. Quickly determining the cause of a break and taking corrective action to prevent further breaks provide a tremendous benefit to paper machine efficiency and sheet quality.

"Our extensive use of synchronized digital video for managing sheet breaks has resulted in a decrease in breaks by an average of 50%. The typical payback on sheet break management alone is three to six months."

The sheet break management system consists of digital video cameras and break sensors, which are strategically located around the paper machine, to provide live time-stamped video clips (called "movies") of sheet break events along with sheet break alarming and a fault statistics/corrective actions database. The cameras continuously record digital video to hard drives contained within video processing computers. When a sheet break is detected, an internal software alarm is activated. The system creates a continuous video clip around the associated time stamp of the alarm event for each video camera. Since each camera is synchronized to the speed and distance of the paper making process, the same part of the sheet is imaged at each position. Movies from each camera are centered about the location on the sheet at which the break occurred that additionally show the paper conditions before, during and after a break.

The movies are stored in a video history log and can be replayed in a variety of ways. Key points and significant segments can be marked and key frames can even be e-mailed if desired. Retrieval of fault statistics, process data, and corrective actions relating to historical sheet breaks are all features which have been implemented in the video sheet break management system.

[1] Note that given the proprietary nature of tissue production, an effort has been made to not share any confidential or sensitive information. No images from tissue will be presented. Images from papermaking will be used to highlight examples.

2.2 Case Study – Identification of the Origin of a Sheet Break

Figures 2.1 through 2.6 are frames taken from an event (sheet break on a papermachine). The figures essentially summarize the working of the system. Figure 2.1 shows the beginning of a break that occurred at the 2nd Coater. Using the views from the cameras upstream of the 2nd coater, the Smart Advisor showed that it was actually a small hole at the trim squirt (wet end) that caused the break. Analysis of this event was conducted in both control rooms as well as the offices of the mill personnel.

Figure 2.1. 2nd Coater DS (Edge Tear / Break)

Figure 2.2. 1st Coater DS (Showing Defect)

2.3 Function: Real Time Web Inspection

The video signal contains a great deal of information on sheet quality, paper machine status and performance. Unfortunately, the motion of the paper is so fast that most interesting effects are not visible to an operator watching the live video. A web inspection system automates the visual inspection process. It does this by analyzing the video signals from each camera as single frames of video i.e. each one is "looked at" as an individual photo, in real time to detect potentially interesting frames with possible anomalies.

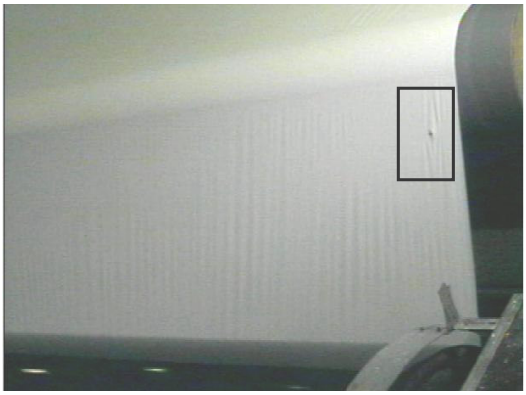

Figure 2.3. Size Press DS (Showing Defect)

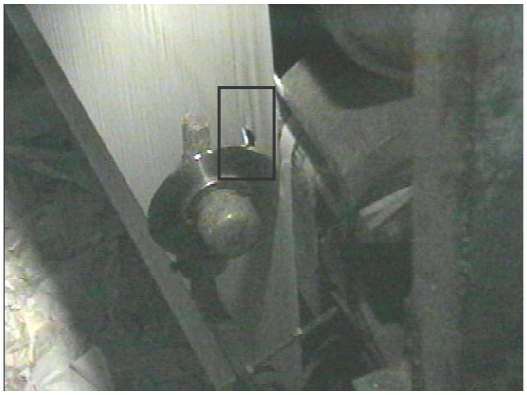

Figure 2.4. Slitter DS (Showing Defect)

Defects from traditional web inspection systems now are automatically analyzed in the machine direction using the sheet break analysis system to determine their origins. Corrective actions are taken to both improve the quality of the paper and to reduce future sheet breaks.

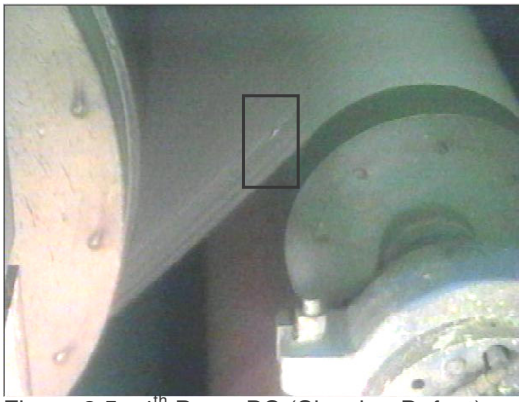

Figure 2.5. 4th Press DS (Showing Defect)

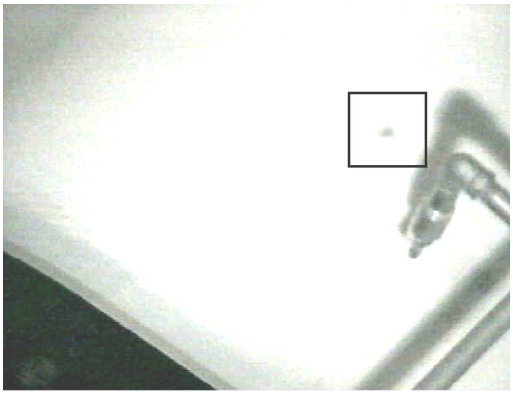

Figure 2.6. Trim Squirt (Showing Defect)

Advancements in pattern recognition techniques, digital video technology, and computer processing have made this new functionality possible. This powerful new technology provides papermakers with the tools to reduce sheet breaks by 50% or more. Quality improvements and production increases will also be obtained allowing for increased profits.

Real time analysis of the video stream from each camera reveals defects, such holes, blemishes, or light or dark spots, and process deviations such as edge drop-off or incorrect take-off angle. Often these defects are moving too fast, or are too transient for operators to notice. A real time web inspection system brings these events to the operator's attention and corrective actions are taken before they have a chance to cause a paper break or produce unacceptable product quality.

"Dust problems had been completely unknown before the Smart Advisor. The number of "UFO's" has dropped significantly now that defects can be classified. Stock drops are also understood better."

2.4 Case Study – Identification of Web Defects

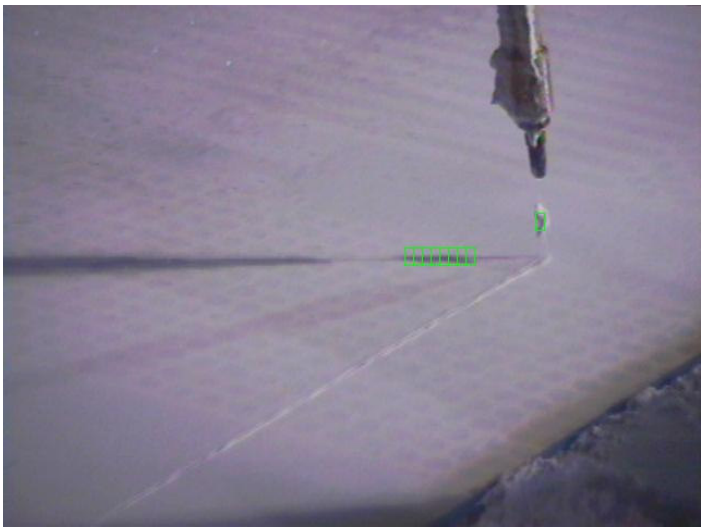

Figure 2.7. Accumulated Pulp Dropping From The Trim Squirt Onto The Sheet.

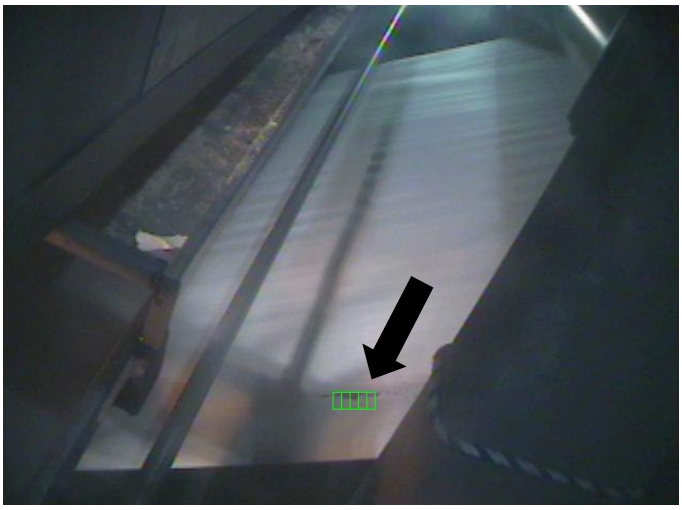

Figure 2.8. Hole Detected By Real Time Web Inspection.

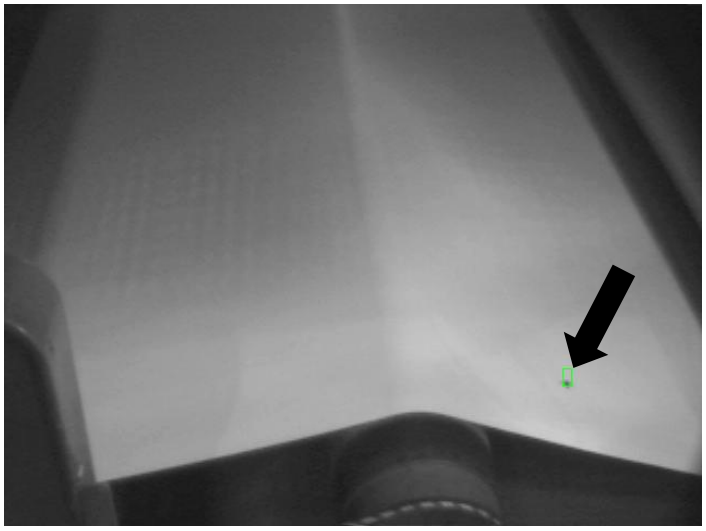

Figure 2.9. Flying Insect Detected By Real Time Web Inspection.

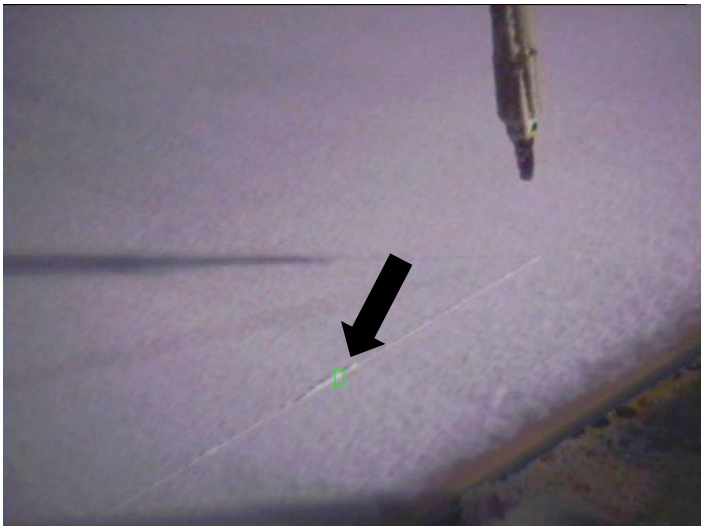

Figure 2.10. Real-Time Web Inspection Detection Of A Bad Trim.

3.0 TECHNOLOGY

Continuous Recording

The system must always keep recording. If a system stops recording at any time while the paper machine is operating, breaks and defects will be missed. Tissue applications require a tremendous amount of video processing (defects, turn-ups, breaks) and require a monitoring system that can ensure real time recording and analysis on a continuous basis.

High Resolution

A high degree of image quality is required to see a small defect. Video must be recorded from each camera at the full resolution of 640H by 480V NTSC (768H by 576V PAL) pixels.

60 Frames/Sec. (50 FPS PAL)

The full FIELD rate with line doubling and interpolation of the video signal should be utilized to capture the dynamic details of a sheet break, and to achieve full coverage of a fast moving sheet.

Remote Control Color Cameras

Highly sensitive (0.5 Lux min) remote control color cameras enhance human vision perception of image quality and depth of field. Remote control cameras provide the ability to control camera and lens parameters such as shutter speed, line sync,

> "Using the Machine Direction Web Inspection capability, I learned more about my machine in the last month than I had in the last fifteen years."

zoom, focus, and aperture, etc. from a computer console, eliminating the need to physically make these adjustments at the camera location.

This can provide advantages in convenience, personnel safety, and in cases where camera locations cannot be accessed when

the machine is running, the ability to make timely changes that would otherwise have to wait for the next shutdown.

Fast Shutter Speed

Use of a high speed electronic shutter, typically from 1/2,000th to 1/100,000th of a second, is required to freeze fast-moving details and eliminate blurring caused by the sheet motion during image capture.

Synchronization

Each camera view should be precisely synchronized to the sheet. Multiple views should presented each looking at the same section of the sheet, not the necessarily the same instant in time. Use of multiple speed inputs gives the ability to account for dynamic draw changes.

Speed and Break Interface

An interface to the machine's control system, including web speed and break information, allows video from multiple machine direction locations to be synchronized.

Real time web inspection

Real time analysis of video from each camera reveals defects, such as holes, blemishes, or light or dark spots, and process deviations such as edge drop-off or incorrect take-off angle. Often these defects are moving too fast or are too transient for operators to notice. A real time web inspection system brings these events to the operator's attention and corrective actions can be taken, before they have a chance to cause a paper break or produce unacceptable product quality.

Application Engineering

Proper mounting of cameras and lights is critical to ensure breaks and defects can be easily seen by operators and to ensure the system is easy to maintain. Engineers should have significant experience with tissue machines, re-winders and packaging lines.

4.0 TISSUE MACHINE MONITORING

Holes and defects are the root causes of the majority of sheet breaks on a tissue machine. Holes are usually created in the creping process where the elasticity is made in a tissue sheet. However, holes and other defects can also be caused by many other factors.

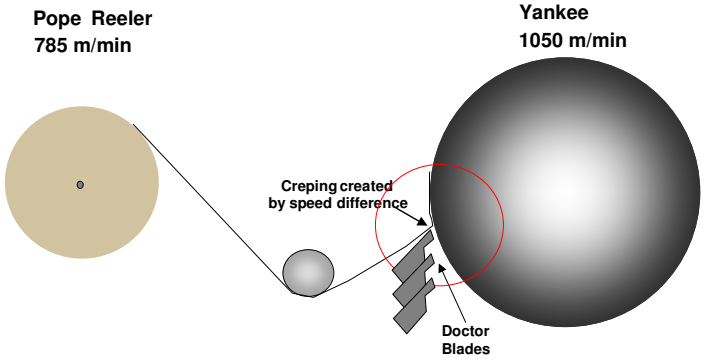

Figure 4.1. Schematic of Tissue Machine (Yankee to Reel).

4.1 Tissue Machine Camera Locations

On classic tissue machines, cameras are placed on both the tending side and the drive side at multiple machine direction positions. These view positions are at the pressure roll which shows the sheet just as it is placed on the Yankee and at the creping blade showing the sheet on the Yankee or after the Yankee as the sheet comes off. Views of the unsupported sheet are captured in the region of the airfoils if possible or in the region just before the scanner. Additional cameras capture the sheet at any on-machine slitters and as the sheet passes onto the reel.

"The automatically synchronized video provides a terrific advantage in the search for the sources of sheet breaks. Prior to the installation of the system, 70% of sheet breaks were from unknown sources. Now only 20% are unknown. The confidence of knowing what really caused a break allowed us to speed the machine up by 4%!"

4.2 Tissue/Paper Machine Case Histories

Case 1. A tissue machine in the Midwest was experiencing problems with turn-ups; one side of the sheet was not getting picked up onto the spool by the vacuum. It would fly about and tear off. The recorded video clearly showed that while the vacuum was strong enough to pull in and grip the sheet at one end of the reel, the vacuum did not extend fully across the spool to grip the entire width of the sheet. This problem was caused by a faulty vacuum coupling on the back side of the spool.

Case 2. Video of a creping blade showed sheet defects in the sheet sticking to the creping blade and causing tear-outs that led to sheet breaks.

Case 3. Video at the reel on a TAD (through air dryer) tissue machine showed that 'feathers' falling into the nip at the reel were causing sheet breaks. Procedures were modified to blow clean the area at turn-ups to prevent repeats of this type of break.

Case 4. On a newsprint machine real-time analysis of video revealed pieces of broke falling onto the sheet just before the calendar stack. These were creating holes that wound on to the reel without creating a sheet break. Without real-time analysis the operators had no way of knowing about holes that were being passed on the winder or possibly to the customer.

Case 5. On a crescent former tissue machine in the Southeast cameras looking at the Yankee dryer just after the pressure roll detected holes in the still-wet sheet, just after it was transferred onto the dryer. The holes could also be seen at the doctor blade, where they caused breaks. The cause was traced to cleanliness problems in the forming section and slime buildup dropping onto the felt, causing excess wetness in the sheet. The mill is looking at possible capital improvements to add showers in the forming section.

Case 6. On a tissue machine where a water jet tail cutter was used to reduce the sheet to a narrow tail at each roll turn-up, breaks were occurring just as the sheet was returned to full width after a turn-up. A front side camera near the pressure roll showed that the water jet was leaving a wet spot on the front edge of the sheet. Video showed that when the excess moisture hit the Yankee roll the sheet boiled out and blistered. Cameras at the doctor blade showed that material was clearly missing at the sheet edge, resulting in the

sheet break. Adjustments to the water jet cutter eliminated this type of break.

Case 7. On a paper machine in the upper Midwest real-time analysis of video of the sheet riding on the under side of the pickup felt showed the edge of the sheet fluttering and dropping off of the felt. The real-time analysis brought this problem to the operators' attention, and allowed them to make vacuum adjustments in the forming section to correct the problem before it became severe enough to cause a sheet break. The operators monitored the real-time analysis results to gage the effectiveness of the vacuum adjustments they were making. They knew that sufficient adjustments had been made when the real-time analysis showed no further edge-flip events.

Case 8. Cameras were placed on a tissue machine looking at the underside of the sheet just before the scanner frame. The front-side camera looked across the sheet and viewed the air-threading chute used the guide the tail at roll turn-up. A trigger signal from the air-thread control was routed to the video system's make-movie 'break' interface. Movies were made from the threading chute and reel cameras every time a turn-up threading was initiated. Video revealed the tail hanging up in the chute when the chute failed to be positioned properly, and the success of the turn-up could be evaluated at the reel cameras.

Case 9. On a newsprint machine, sheet breaks that appeared to occur at the reel were traced back to defects at the center roll causing long tear-outs. Tears were taking until the sheet reached the reel to progress to the edge of the sheet and cause a break. Real-time analysis showed the root cause of the break, and gave advance notice before the break occurred.

Case 10. The turn-up signal was similarly used on tissue machines to trigger movies in the reel section following a re-build of the pressure arms and nip relief hold-off cylinder. The resulting video was used to analyze the full sheet turn up and fine tune the action of the pressure arms and nip relief.

5.0 REWINDER MONITORING

Often rewinders are the bottleneck in tissue production. These machines run at a very high rate of speed. Digital video can help determine if breaks are caused by defective tissue from upstream or a fault in the Rewinder itself.

5.1 Rewinder Camera Locations

The optimum digital camera locations for a center winder with 100-inch trim width are:

- 4 cameras across the bed roll
- 1 camera on the tending side looking across the sheet adjacent to the front of the turret.
- 1 camera between the calender rolls looking down at the entire sheet.
- 1 camera as a rover to be placed at the current problem area. i.e. core loading, perf cutters and anvils, choppers both drive and tending side.

For a winder of larger width, it is necessary to increase the number of cameras at the bed roll to maintain the necessary resolution for detection of issues associated with the smallest components of the winder.

5.2 Rewinder Case Histories

Case 1. At a Midwest towel manufacturer a video system was focused on a Perini surface winder. The converting operation involved 2 logs, a white layer and a 2nd white layer with printing. The 2 layers are glued, pressed together and embossed with a pattern before being wound onto logs of the end-product diameter. The Perini winder winds product onto cardboard cores. The plant was having a problem with rolls that were loose on the core. The operator's first response was to increase the nip pressure. This caused rolls to wobble and become egg-shaped. By examining the video frame-by-frame when the cores were being loaded, it was revealed that one of the leaf springs that was supposed to hold one end of the core was out of adjustment, so that the core was not being loaded properly. The video system revealed the true source of the problem, and after it was corrected the nip pressure was returned to normal and production could resume without further problems.

Case 2. On several tissue re-winders video is used to detect holes and flaps in the sheet coming from the tissue machine, that cause breaks on the winder. A determination can be made as to whether breaks are due to the winding operation or defects in the sheet. In addition, cameras have been focused on banks of slitters before the sheet is re-wound. When a wreck occurs the video is analyzed to determine not only what happened, but also which slitter is responsible for originating the problem.

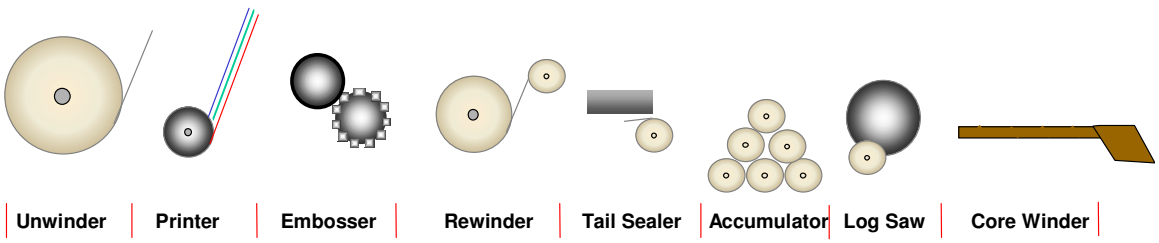

Figure 5.1. Components of the towel converting process.

6.0 PACKAGING LINE MONITORING

"As part of a corporate evaluation, we tested (the system) at our plant in New Jersey. After two weeks, we solved several lingering issues allowing us to increase line output and reduce operating costs. From the start, people at the plant were comfortable using (the system). We will be highly recommending it to all of our plants in North America."

Digital video monitoring can be used to monitor accumulators, log saws, wrappers, case packers and palletizers. The systems allow operations to see the root cause of intermittent jams. Engineers can then correct the issue to eliminate repeat problems and increase line efficiency.

Using digital video monitoring systems in a packaging lines area requires increased flexibility. Operators need the ability to quickly move a camera to a machine that has been jamming intermittently. If the operators had time, they could connect the monitoring system electrically to a photo-eye sensor or PLC at the problem line equipment. This external impulse would tell the monitoring system exactly when the jam occurred, allowing the system to process video for the operator.

Unfortunately, in a packaging operation, there is not time to make this electrical connection. The ability to just point a camera, walk away and return after the jam has occurred is important. Operators need to be able to scroll through recorded video to see the jam in slow motion. They need to be able to quickly setup the camera without requiring an electrical resource for support.

6.1 Packaging Line Case Histories

Case 1. A 'twist and tuck' wrapping machine which wraps individual rolls of toilet tissue on a packaging line, was jamming periodically, putting out rolls with out any wrap, and requiring a stop to rethread the wrapping material. The wrapping machine was required to perforate the wrapping stock, and burst it into sheets for wrapping the individual rolls. Analysis of the video revealed that the wheels that burst the sheets were uneven, causing one side to burst too early, flip up, and cause the jam.

Case 2. A tissue mill in the Southeast US was plagued by an intermittent problem at the log saw infeed. Once or twice per day, a log would enter the saw at an angle and would jam. The mill suspected a problem with the timing operation. A digital video monitoring system was placed at the transfer from the accumulator to the log saw. After a few hours, a log jammed in the cutting chamber. By reviewing the recorded video, the mill determined that when the accumulator started up from a standing position, the failing log could bounce. In this case the log pusher paddle would travel past the end of the log as it bounced. When the log landed on the paddle, it would be angled to the side and would jam in the log saw chamber.

7.0 CONCLUSION

With digital video monitoring, the root cause of web defects, web breaks and packaging line jams can be easily found. Engineers can make modifications or adjustments to eliminate repeat upsets. Operators can reduce the number of breaks on tissue machines and rewinders by 50% and can obtain speed increases of 7%. Line efficiencies on packaging lines can be increased by 3-8% by eliminating repeat, intermittent line jams.

"Many of these fixes and advancements are (or will be) possible because the operators and production staff "know" what the problem is. They don't have to guess or spend large amounts of time on investigation."

Advancements in pattern recognition techniques, digital video technology, and computer processing have made this new functionality possible.

"A steadily recurring hole was observed in the system. Using the (system), operators calculated the number of frames between holes and determined the frequency to be equal to that of a felt. The felt had a hole in it and was replaced, saving tons of wasted tissue."

Digital video monitoring systems have been developed to fulfill the special requirements of tissue production. Continuous recording, environmentally sealed camera and light components, machine vision capability for tissue web monitoring, and application experience all provide the required solution to effectively monitor tissue manufacturing.

"If you tried to take the system out of the mill, you probably wouldn't make it out the door alive."