INTELLIGENT ROLL PLATFORM FOR BETTER RUNNABILITY

By

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ABSTRACT

An intelligent roll is a mechatronic system consisting of a roll in a web handling machine that is also used as a transducer for sensing cross machine tension or linear load. The intelligent roll has electret film force sensors mounted on it in a helical arrangement. The force sensor measures the force applied by the product that is being produced, such as a paper web and thus provides information about the behavior and quality of the product. In addition to the force sensors, the intelligent roll system has an electronic signal processing module on the roll end along with a digital radio link to transmit the data from the rotating roll. The receiver is connected to an automation network.

Using an intelligent roll as a reel or winder drum enables online measurement of linear load profiles in reeling and winding. The linear load profile correlates with roll hardness and diameter profiles. An intelligent reel drum combined with actuators such as calender zone controls or coat weight profilers in a closed loop control system enables response to profile-related quality variations.

Another application is to use an intelligent roll as a measuring roll that monitors the tension profile online without separate scanning devices. With online measurement, the tension profile can be optimized with closed loop control.

Intelligent roll technology also enables temporary process and runnability analysis measurements by using tape-mounted sensors. Problems such as loose web edges, off-machine coater web shifting, winding problems, and reeling defects have been solved with these measurements.

Besides paper making, intelligent rolls may be used in web handling applications such as: printing, converting, plastic film production, fabric production, etc.

Three cases of using intelligent roll technology are presented in this paper:

1. Online control of web tension profiles
2. Online control of roll hardness / diameter profiles and replacing inaccurate thickness measurement
3. Finding and removing the reason for lateral web shifting in an off-machine coater.

NOMENCLATURE

C	Capacitance
C_s	Capacitance of the sensor film (pF)
Q	Charge
S_q	Sensor sensitivity (pC/N)
V	Voltage
ΔF	Change in force (N)
ΔQ	Change in charge
ΔV	Change in voltage

INTRODUCTION

It is well known that variations in the tension profile of a web adversely affect runnability in web handling processes [1], [2], [3]. In the paper making process, these variations can lead to web breaks, flutter, wrinkles, and calendar cuts [2]. In the printing process, tension profile variations can cause web breaks, wrinkles, and color registration errors [2]. In, [3], the relationship between tension profile variations and the development of wrinkles in printing presses were specifically studied. Historically, profiles such as basis weight, moisture and caliper were measured and controlled in the paper making process [2]. However, tension profiles did not attract much attention until the late 1980's and early 1990's.

As a result of the interest in tension profiles, a variety of sensors were developed. Longitudinal web tension has typically been measured with a roll mounted on load cells; one load cell at either end of the roll. This arrangement provides a signal that represents the average value of the longitudinal tension but provides no information about the tension profile. A small improvement on this setup can be achieved by mounting multiple load cells under the bearings of sectional rolls. Perhaps a half dozen discrete tension levels can be measured in the cross machine direction utilizing this method. However, costs rise significantly as additional bearings and load cells are required and resolution is on the order of one meter. In addition, proper calibration and interpretation of the signals can become confusing.

In [1], a novel three load cell arrangement was used to measure the forces and bending moment on a web. A load cell mounted axially on a roll was used to measure shear and two load cells mounted in the traditional position below the roll were used to measure tension and the bending moment on the web. Additionally a tension profile was measured with an electro-acoustic device.

Tension profiles were measured in [2] with a device called a Tenscan that used a laser beam to measure the transit time of sound waves passing through a web. A speaker was used to cause sound waves in the web and the laser was used to measure their speed. Similar to the equation for wave speed in a string under tension, this sensor relied on the relationship between wave speed, tension, and basis weight. However, basis weight can vary both in the machine direction and the cross machine direction which can lead to measurement errors. The Tenscan unit was portable but cumbersome and required 50 cm of space in the machine direction for mounting. It was also relatively slow and took approximately one minute for a profile. Typically, 10 profiles were measured for the parent roll in a reel and an average profile was calculated from those.

In [4], a device called a CTsensor was used to measure tension profiles. This device was a roll that consisted of numerous rotors floating on air lubricated bearings. The pressure differential between the top and bottom of the bearings was related to the force of the web on each rotor. Differential pressure transducers were used to measure the air pressure and were sampled by data acquisition equipment. In addition, web speed and temperature effects on the measured signal were negligible and the cross machine resolution was 55 mm. However, each rotor needed to be calibrated individually by applying a variety of loads and curve fitting the voltage outputs to the loads. In addition, the rotors could stick if ink or other debris became lodged between them which would cause erroneous readings.

A non-contact tension profile sensor was used in [5]. A beam deflected the web, but there was a thin layer of air between the round surface of the beam and the web. Pressure in the air layer was measured through small orifices in the beam and related to web tension. The resolution is based on the spacing of the orifices which are typically 100 to 300 mm. However, the web speed must be over 500 m/min for the air film to develop limiting this sensor to higher speed processes.

This paper introduces the intelligent roll which is a new tension and nip load profile sensor. It can be quickly calibrated, is not speed limited, its output signal is independent of basis weight, has a resolution of approximately 50 mm, and requires no machine direction space for mounting. The intelligent roll is a mechatronic system that consists of a high-precision roll body with helical grooves machined in it, force sensitive electret film sensors mounted in the grooves, roll covers, signal processing electronics, a digital radio transmitter, wireless power transmission, and a receiver connected to the mill automation network [6]. Figure 1 illustrates the construction of an intelligent roll. A portable version of this system, which is easily transported, uses the same technology for temporary measurements.

The intelligent roll technology creates new possibilities for optimizing the runnability properties of a web handling process. An intelligent roll can be used in place of a tension roll to measure web tension profiles online, without separate scanning devices. However, unlike previous tension profile measurement devices, the same technology can also be used for nip load profile measurement. An intelligent roll can be used in place of a reel drum to allow the measurement of both the nip load profile and the roll profile online. This capability facilitates the online control of roll profiles and web tension profiles in permanent installations. The portable version of this system allows almost any roll to be converted into an intelligent roll by using tape-mounted sensors. This technology enables temporary roll profile, nip load profile and tension profile analysis to be performed by field technicians. In this manner, economic benefits can be achieved by solving difficult problems without large capital investments.

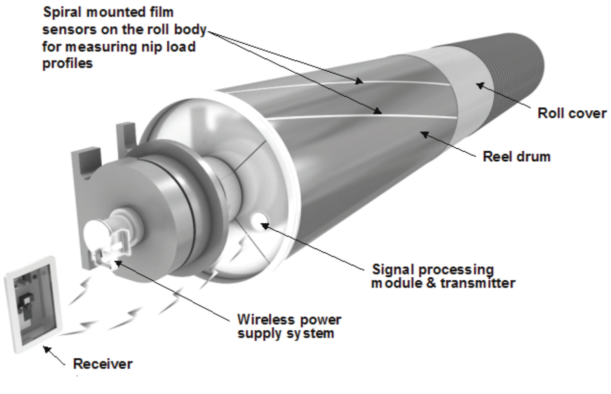

Figure 1 – The intelligent roll and its components

The special feature of the intelligent roll is that external measurement devices such as scanners are not needed. An intelligent roll is just like any other roll in the process so this makes it possible to view how the web tension or nip profile actually acts in the production line. Moreover, it may be located in various positions in the process, wherever the tension profile is critical or the nip / paper roll profile needs to be measured. The portable system enables equipping the line with several profile measurements simultaneously.

The first portion of this paper discusses the sensing principle of the intelligent roll. The next part of this paper discusses the three implementations of the intelligent roll. The third part of this paper provides three case histories of the intelligent roll technology. The remaining part of this paper briefly explains other industries that this technology can be used in.

SENSING PRINCIPLE OF THE INTELLIGENT ROLL

An electret is a dielectric material that has quasi-permanent charge storage and hence, a quasi-permanent electric field. It is analogous to a permanent magnet which has a permanent magnetic field. Electrets have been studied for some time, but interest increased in the 1960s with the development of polymer dielectrics that exhibited piezoelectricity [7]. In the mid-eighties, a novel porous polymer electret was developed in Finland that had much higher levels of piezoelectricity than previous materials [7], [8].

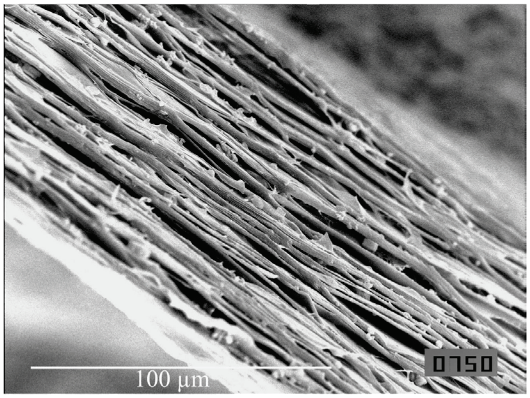

Figure 2 – Scanning electron microscope picture of a porous polymer electret.[1]

Porous polymer electrets are manufactured by stretching the film in two perpendicular directions to create voids as shown in Figure 2. The internal surfaces of the voids are then charged to opposite polarities with a corona method so they become macroscopic dipoles [9]. The structure of a simplified version of the sensor resembles a capacitor with two conducting electrodes separated by the electret which is a dielectric. In operation, when the material is compressed by an external force, the voids in the electret decrease in thickness which decreases their dipole moment. This causes charge separation to occur on the electrodes of the sensor as illustrated in the simplified diagram in Figure 3.

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[1] EMFi® electret film, Emfit Ltd, Konttisentie 8 B, 40800 Vaajakoski, Finland, www.emfit.com.

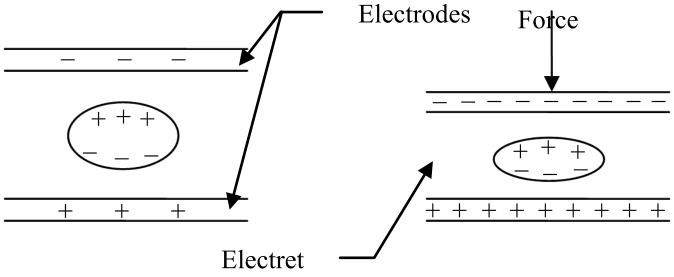

Figure 3 – An electret sensor with one void.

As a result, an open circuit voltage appears on the electrodes according to the relationship between charge and voltage for a capacitor {1} [8].

$$V = \frac{Q}{C} \tag*{\{1\}}$$

In practice, the voltage at the electrodes of the sensor can be calculated with {2}[9]. It should be noted that this sensor generates output voltages only for changes in force. Steady state or constant force will not cause an output voltage to be generated.

$$\Delta V = \frac{\Delta Q}{C_s} = \frac{S_q \Delta F}{C_s} \tag*{\{2\}}$$

IMPLEMENTATIONS OF THE INTELLIGENT ROLL

Nip Load Measurement

Using an intelligent roll as a reel drum, as shown in Figure 4, provides a new system for online nip force profile measurements, providing valuable information about paper web properties. The nip profile measured at a reel has a direct correlation with the diameter and hardness profile of the paper roll. The reeling nip load profile clearly shows the peaks and valleys that are caused by variations in the paper thickness profile. The high resolution of the profile measurement is based on the inherent nature of roll building. Thousands of paper layers are reeled on top of each other while winding the parent roll, so the thickness variations are accumulated and make relatively large variations in the parent roll diameter profile. Due to this, it is advantageous to replace old manual parent roll hardness measurement systems.

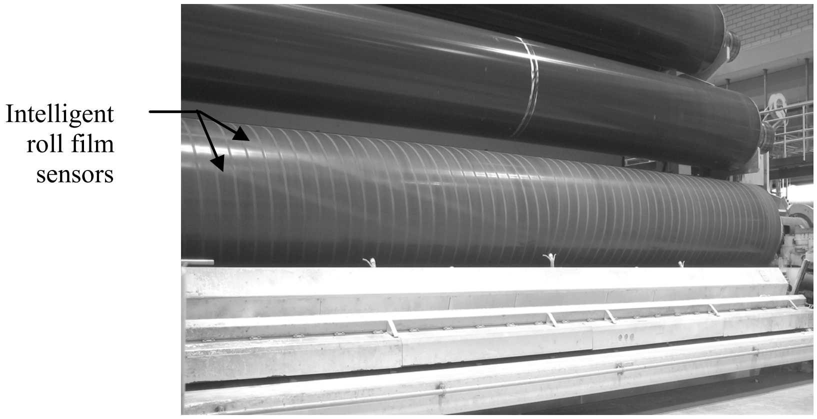

Figure 4 – An intelligent roll installed in a paper machine reel.

An intelligent roll not only facilitates control but also reduces reeling problems. Since it measures the reeling nip load profile directly at the nip, an intelligent roll immediately reveals force peaks, discontinuities in reel build-up, skewed nip profiles and “carrot-shaped” rolls. Force control problems caused by friction and wear in the machine parts are also exposed. This results in less broke from reeling-related quality defects.

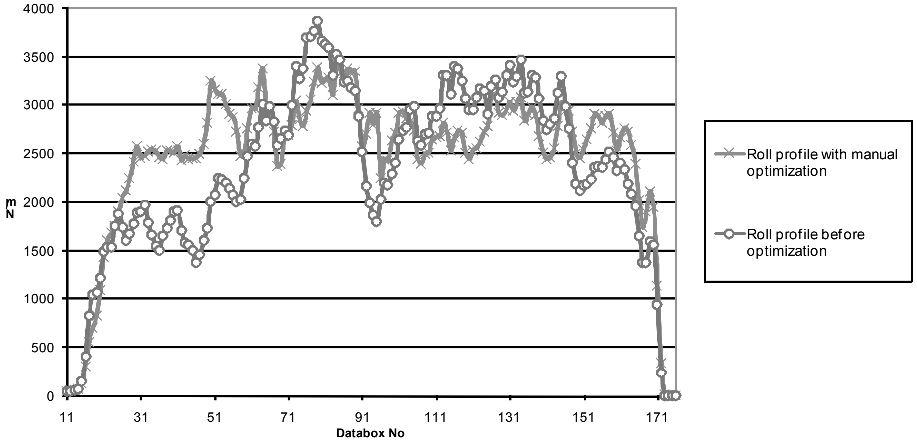

Figure 5 – Example of a reeling nip load profile that shows the peaks and valleys in the roll that are derived from variations in the paper thickness profile. The graph also shows an example of a response obtained manually with multinip calender SYM-roll profiling.

Using an intelligent roll as a reel drum combined with actuators such as calender zone controls, calender induction profilers, basis weight profilers or coat weight profilers allows for closed loop control of roll profiles. This enables an immediate response to profile-related quality variations and runnability problems, and reduces the recovery time after grade changes.

Tension Profile Measurement

Another application for the intelligent roll is to monitor the full-width tension profile continuously, online, and without using any separate scanning devices. Also, with tension profile and tension level measurement, the accuracy is improved when compared to traditional methods. With an intelligent roll, the tension is measured directly between the paper sheet and roll body. Therefore, the dead weight of the roll and thermal expansion have no effect on the measurement system.

Using an intelligent roll to measure the tension profile can also be combined with closed loop control. There are two basic tension profile control topologies that can be used to improve runnability. The first topology is based on traditional moisture profile control using the paper machine press section steambox as an actuator. Moisture profile measurement and control are applied as normal. Tension profile optimization is added to the system in cascade with the moisture profile control. The tension profile is measured by an intelligent roll located in a suitable position and a moisture profile set point is calculated by the tension profile controller. This set point is sent to the moisture profile controller. A cascaded control system such as this is well understood and straight forward to tune. The tension profile control has a certain range that it is allowed to operate in which limits the moisture profile variation. Thus, the tension profile may be optimized while the moisture profile is kept within its limits.

The other topology used for web tension profile control is based on two or more actuators affecting the tension and moisture profiles separately. The first actuator (either press section steambox or 1st drying section moisturizer) is used to control the tension profile and the second actuator (a moisturizer) is used to correct the moisture error of the end product. This topology can decouple the moisture and tension control. It is also possible for the control systems to limit each other to reduce the moisture error caused by too much profiling in the press section steam box. The system can also be tuned with optimal weighting for each actuator vs. each measurement. For an example, the press section steam box can have 80% weight for controlling tension profile and 20% weight for controlling moisture. The second moisturizer can have the opposite weighting: 20% to control tension profile and 80% to control moisture profile.

Portable Intelligent Roll Systems for Process Analysis and Measurement

Portable intelligent roll technology brings a new online nip load and tension profile analysis tool for paper and board makers and maintenance experts. This portable system provides information about CD and MD tension profile variations and nip load profiles. The portable system allows the use of intelligent roll technology quickly and cost efficiently.

The portable technology requires the installation of intelligent roll sensors onto a roll surface. A signal processing module with a transmitter must be attached to the roll head or shaft. The intelligent roll instruments provide a complete CD profile on each full turn of the roll. The measured profile information is transmitted with a wireless link to a receiver and from there to a PC. The portable system allows large amounts of data to be collected in a short period of time.

Figure 6 – Installing portable measurement sensors on a roll surface.

Parent roll build-up problems detected online with portable intelligent roll system. The portable intelligent roll system measures the reeling nip load profile online. It shows reeling defects and the quality of the parent rolls. For example, variations in parent roll quality derived from the paper thickness profile are clearly shown in the measurements. The intelligent roll system detects force peaks, discontinuities and skewed nip profiles during parent roll build-up. With this information, operators can adjust reeling parameters and troubleshoot profile related reeling problems that originate in earlier process stages. The portable system also makes it possible to perform bump tests to find responses from calender steam boxes, zone control rolls, etc., and thus help to optimize the paper web properties. In addition, the system can be used to detect wear in reeling nip mechanics and controls. For nip load measuring purposes, the portable system can be located on the reel, rereeler, calender wind-up, winder, or anywhere where precise information on the wind-up process is needed.

Tension profile problems detected online with portable intelligent roll system. Runnability problems such as slack edges, wrinkles, web shifting and poor edge quality are typically caused by uneven tension profiles. The tension profile measurement can be located before the sizer, reel, calender, coating station or winder, or anywhere where the tension profile is critical. The portable intelligent roll system makes it possible to test the response of different actuators and optimize the paper web properties. The tension profile can be affected by dryer section moisturizers, infra dryers, steam boxes or machine calender, for example.

THREE CASES OF USING INTELLIGENT ROLL TECHNOLOGY FOR IMPROVING RUNNABILITY

This section of the paper introduces three example cases of using intelligent roll technology to improve runnability:

1. Online control of web tension profiles
2. Online control of roll hardness / diameter profiles and replacing inaccurate thickness measurement
3. Finding out and removing the reason for off-machine coater web shifting.

Online Control of Web Tension Profiles

A liner board production line had difficulties with runnability of their film sizer press. Due to loose edges on the web, there was often fluttering and wrinkling before the sizer. To remove wrinkling, the web tension level had to be increased 300 N/m higher than it otherwise would have been. A higher tension level naturally caused a higher amount of web breaks and thus caused problems in the production.

Intelligent roll based measurement and control was implemented to improve the web tension profile. The tension profile measurement was located before the sizer.

Controlling the tension profile is most effective when done as early as possible in the paper making line. In the drying section, the web is stretched and dried at the same time causing permanent changes in the tension profile. The shape of the profile can be modified with a moisturizing device located at the beginning of the drying section. Therefore, a moisturizer on the 1st drying section was used to control the web tension profile in this case. Another moisturizer at the 2nd drying section was used to remove the moisture error from the end product. Due to the location of the second moisturizer, it had only a small effect on the tension profile. Thus, the effects of the 1st moisturizer dominate the shape of the tension profile. Figure 7 illustrates this control topology.

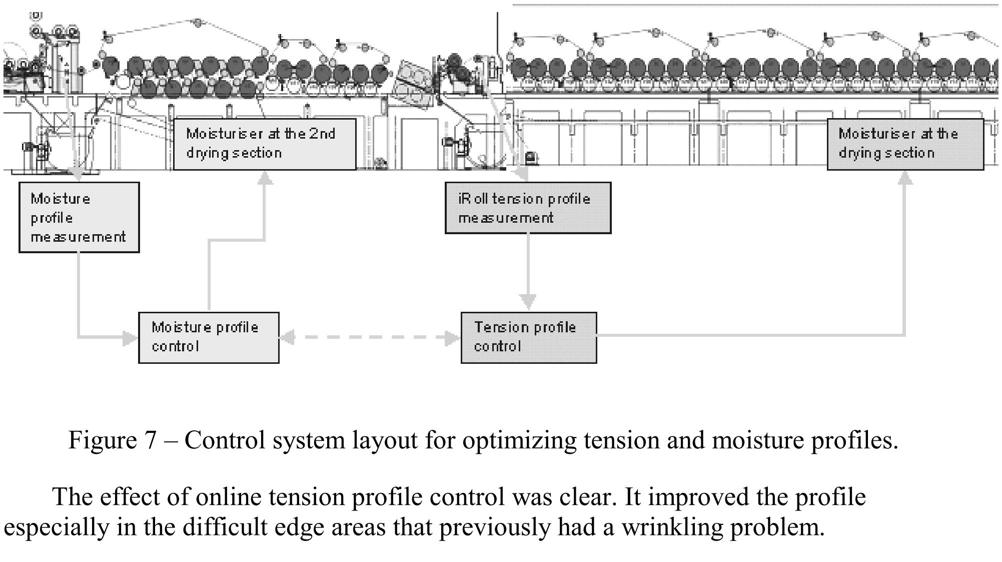

Figure 7 – Control system layout for optimizing tension and moisture profiles.

The effect of online tension profile control was clear. It improved the profile especially in the difficult edge areas that previously had a wrinkling problem.

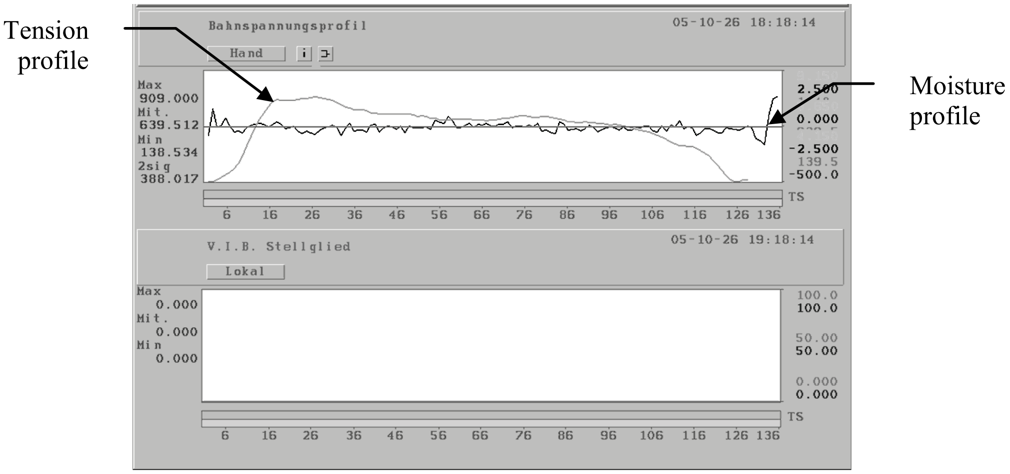

Figure 8 – Tension profile before the control system was turn on.

Figure 8 illustrates the tension profile before the control system was turned on. There is looseness on the web edges and the tension profile is skewed.

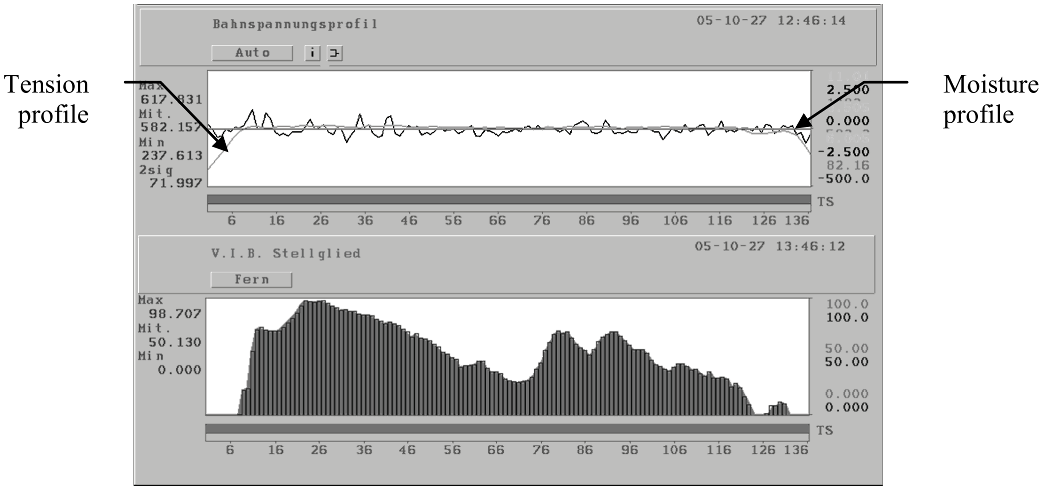

Figure 9 – Tension profile after the control system was turned on.

Figure 9 illustrates the tension profile after the control system was turned on. The bar graph in the bottom half of the figure illustrates the target profile for the moisturizer that was used as an actuator for the control. From Figure 9, it is seen that looseness on the web edges was reduced significantly and the tension profile is now flat.

With the control system, the tension profile was clearly improved and the end product moisture profile still remained within limits. The improved profile reduced wrinkling and enabled a lower web tension which resulted in fewer web breaks.

Online Control of Roll Hardness / Diameter Profiles and Replacing Inaccurate Thickness Measurement

In the past, it has been difficult to control the thickness profiles of glossy paper grades such as SC, LWC or WFC due to difficulties in scanning the thickness profile. Inaccurate thickness profile measurement has caused reeling problems especially in the roll edge areas and after grade changes. Small thickness and density profile variations accumulate into large diameter and hardness variations of the paper roll when thousands of layers of paper are reeled on top of each other. This has led to runnability problems in reeling and winding due to bumpy rolls as well as reclamations from printing houses.

Intelligent roll reeling nip load profile measurement makes it possible to accurately control the roll structure and thus ensure good runnability in winding and printing. An SC-A paper production line with online multinip calendering was equipped with an intelligent reel drum and a calender control system using reel drum roll profile measurement as shown in Figure 10. The roll hardness and diameter profile is measured through an intelligent roll nip profile. The control system calculates the set point for the zone control roll in the calendar to optimize the paper roll structure.

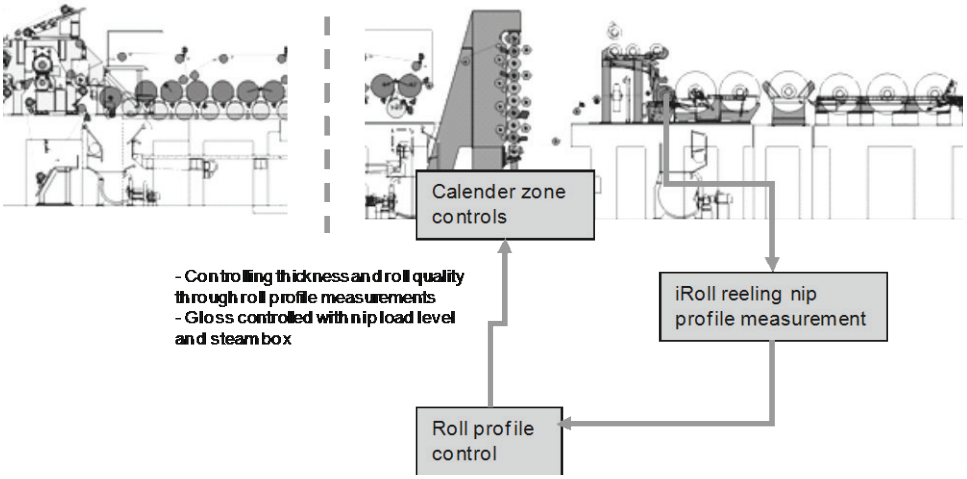

Figure 10 – Roll profile (hardness and diameter) control topology using an intelligent roll.

Figure 11 clearly shows the quality of the roll that is being produced. At the beginning, the roll profile control has been turned off. Without the control, the roll profile has large variations and the roll has very soft edges. This obviously leads to runnability problems during winding. When the variations in the roll become large enough, it is possible that the roll may burst due to excessively high internal stresses.

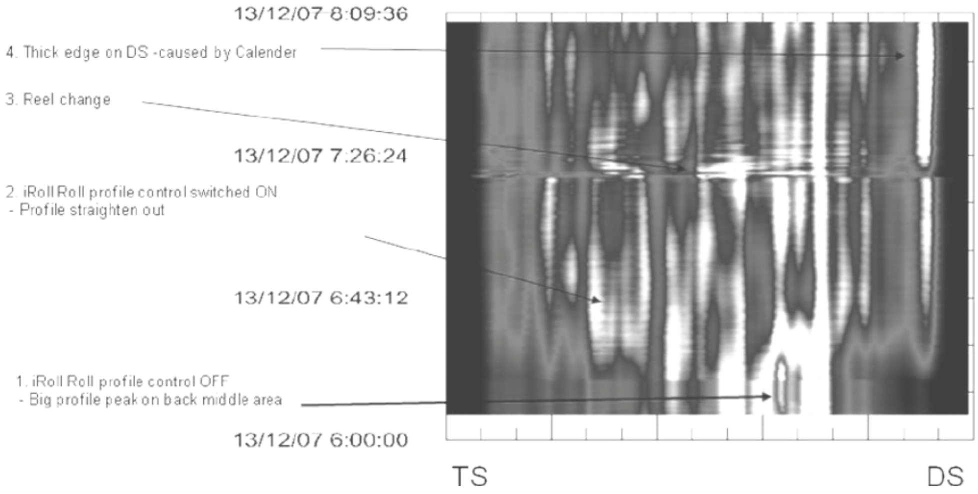

Figure 11 – Roll profile as a color map measured with an intelligent roll.

After turning the profile control on, the profile levels out. Some narrow variations remain in the profile because of the resolution limitations of the zone controlled calender roll. This measurement also reveals two narrow variations in the profile that are caused by worn out calender rolls. The accurate measurement of an intelligent roll allows roll wear to be detected early so that corrective measures can be taken to avoid unplanned down time.

With the online roll profile control, the SC-A production line has had increased efficiency and improved runnability at the winder. The intelligent roll based control system also makes running the line more stable and reduces the recovery time after grade changes.

Finding and Removing the Reason for Lateral Web Shifting in an Off-Machine Coater.

A mill producing high quality wood free coated paper had a constant problem with lateral web shifting in an off-machine coater. The lateral movement caused web breaks especially during splicing and also caused difficulties in web edge cutting. The reason for the web shift had been a mystery for years and a variety of modifications were made to the paper making line to attempt to fix the problem. However, none of the modifications were effective. Over the years, the speed of the line was increased and the web shifting became a bottle neck for increasing the production. Also time and material efficiency of the line was lower that it could have been which caused additional production costs and indirectly higher energy consumption.

When the portable intelligent roll system was developed, it was decided to start tackling the web shifting problem with it. It was assumed that some kind of tension profile variation had to be the reason for the web shifting. An extensive analysis was done to find the cause of the variation. The paper making line was equipped with several tension profile sensors, roll nip load profile sensors, and web edge sensors. Installing several portable intelligent roll systems along the line allowed the profile effects of each sub-process to be separately identified. During actual production, it could be seen where all the effects of the tension profile were coming from. Web edge position sensors were installed to measure the lateral translation of the web.

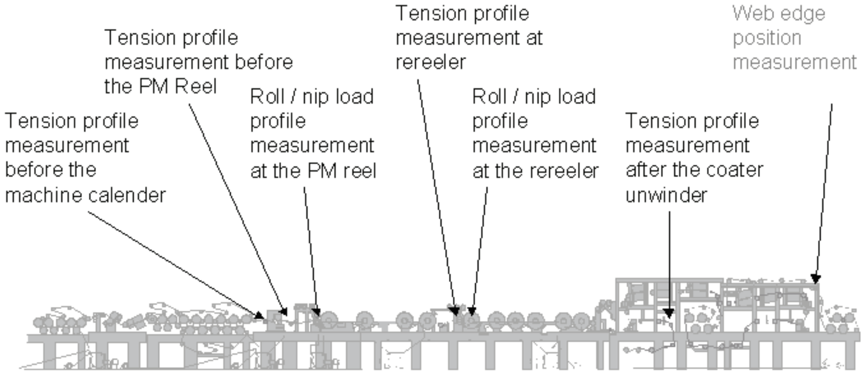

Figure 12 – Portable intelligent roll system and web edge position measurement locations.

When the measurements were complete, the first observation was that the off-machine coater web shifting (detected by changes in the web edge position) had a direct correlation with the skewness of the tension profile measured at the coater. The skewness was quantified by fitting a straight line to each measured tension profile (approximately one profile per second was measured) and calculating an angular coefficient of the line. These coefficients where presented in the time domain for each paper roll and compared with the measured edge position of the web. In this manner, it was demonstrated that the skewing of the tension profile was the reason for the web shifting. After this, it needed to be determined where skewing in the tension profile was coming from.

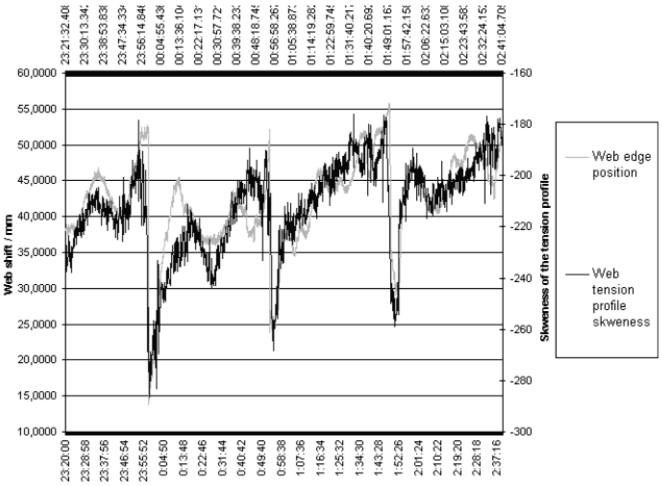

Figure 13 – Correlation of the web shifting and tension profiles at the coater. A skewness index was calculated from web tension profile (presented above with black line) and compared with web edge position (grey line) at the off machine coater.

The second observation was that tension profiles measured at the paper machine did NOT have correlation to the tension profile at the coater. This was a small surprise for the analysis team because at the beginning it was expected that the tension profile errors would probably come from the paper machine wet end. However, according to the measurement, this was not the case and the paper machine with all of its sub-processes could be ruled out.

The third observation was that the tension and roll profiles at the rereeler had quite good correlation to the tension profiles at the coater. The team started targeting their work on the reeling equipment between the paper machine and coater. It had to be that either the rereeler or the paper machine reel was the cause of the tension profile variation.

Finally the paper machine reel was targeted and a nip load profile was measured there with a portable intelligent roll system. It was found that the nip profiles measured from the paper machine reel had excellent correlation to the tension profile at the coater. Because the paper machine reel was the first place along the line where this correlation was found, it had to be the primary reason for the web shifting.

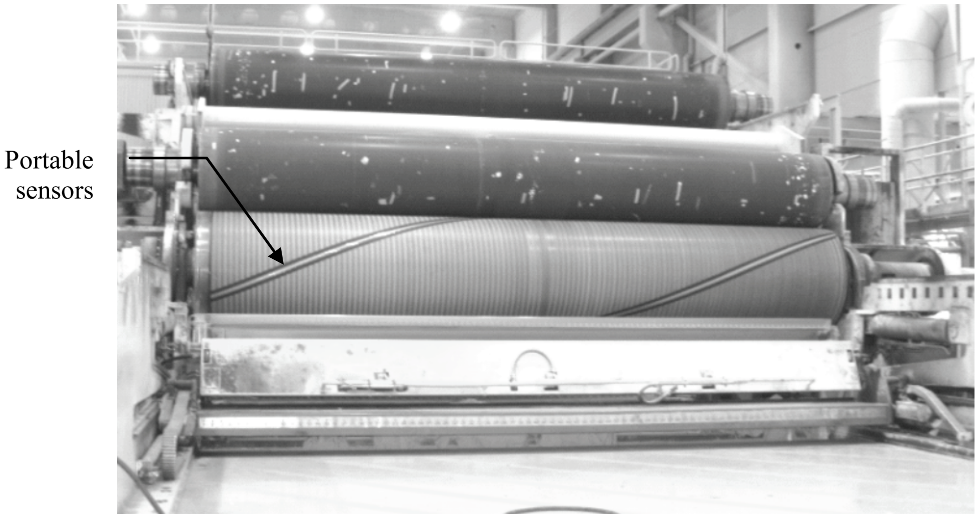

Figure 14 – Portable intelligent roll system installed on the paper machine reel drum.

When the paper machine reeling nip was found to be the reason for the tension profile variation, it was concluded that the WOT-profile (Wound On Tension) of each roll was skewed and the skewness also changed during the reeling. When the rolls with variations in the WOT were unwound at the coater, the web shifting occurred. The nip load controls of the reel were updated and adjusted to have a level WOT Profile. Also, the reeling recipes where adjusted to create a better roll structure.

After the update of the reel, the tension profile changes at the coater were reduced significantly. When the tension profile did not change rapidly during the unwinding, the web behavior was stable and web shifting no longer occurred.

INTELLIGENT ROLL FOR OTHER INDUSTRIES

Besides the paper and board machines, intelligent roll technology may also be used to measure tension and nip load of web materials in other industries. The portable intelligent roll analysis can also used in these applications as well. Intelligent roll based systems are possible for measuring:

- Web tension in the machine direction

- Tension profile in the cross machine direction
- Nip profiles between rollers
- Roll profiles in reeling or winding processes
- Web edge positions

Due to the capabilities of the measurement system, it can be used for a wide variety of materials besides paper. Even measuring web properties with very low tension levels, e.g. 10N/m, is possible. The industries where intelligent roll technology can be used include:

- Printing
- Pulp drying
- Converting
- Plastic film production and utilization
- Metal film production and utilization
- Textile production and utilization

CONCLUSION

This paper presented a novel tension and load profile measurement system based on new developments in polymer electret film technology. This intelligent roll measurement system turns the roll into a mechatronic sensor that can be located in place of a conventional roll in a web handling process. The roll can then be used for tension profile measurement or nip load measurement. In addition, a portable version of the measurement system can be installed temporarily to troubleshoot web handling problems on a process line.

Three cases were presented showing the use of the intelligent roll in actual web handling lines. An intelligent roll was used to succesfully improve runnability of a liner board machine by providing feedback to moisturizers for controlling the tension profile. In another application, the intelligent roll was used to control roll hardness and diameter profile at a reel by using a calender profiling roll as an actuator. This improved runnability and efficiency on the winder. In the last case, the portable version of the system was used to identify and correct the cause of skewed tension profiles which caused lateral translation of the web in an off machine coater.

Although all examples and applications presented involved paper webs, the intelligent roll is not limited to this web material. It can be used with polymer film, metal film, tissue, and even webs made of woven materials. These other materials provide new areas for future development of the intelligent roll.

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Intelligent Roll Platform for Better Runnability

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Name & Affiliation	**Question**
Ron Ledge, Proctor & Gamble	What range of pressures and tensions does this instrument operate over? How do you get a cross-direction position wise signal out of a single strip sensor?
Name & Affiliation	**Answer**
Bob Bettendorf, Metso Paper,USA	I am unsure of the range of loads we can measure. I know we can measure fairly light loads because we have used it on paper and tissue. Nip loads in a reel can easily reach 25 pli (43.8 N/cm), so the range must be quite a bit higher if we are using it on a reel. To get multiple samples out of a single roll sensor, we have a encoder or a one-pulse per revolution counter on the end of the roll. We synchronize our sampling with the roll position so we can consistently take a sample at the same position of the roll.
Name & Affiliation	**Question**
Clarence Klassen, KlassEngineering	Does it require calibration and if not, why not? Can you describe how it would sense web tension?
Name & Affiliation	**Answer**
Bob Bettendorf, Metso Paper, USA	The device does require calibration. You have to calibrate the voltage output for a known applied pressure. We infer web tension from the pressure created between the web and the roller. It is just measuring a pressure similar to the pressure created by a nip. There is really nothing different about it.
Name & Affiliation	**Question**
Clarence Klassen, KlassENgineering	When using the roller for the winding nip or reel where there are components of pressure due to both web tension and nip load will the device still work?
Name & Affiliation	**Answer**
Bob Bettendorf, Metso Paper, USA	In this case we there is a component of pressure from the nip load and then we have a second component of pressure from the tension. The device would read the component of pressure from the nip load because the tension would come to be tangential to the sensor. There is no sensitivity for that sensor in that direction.
Name & Affiliation	**Question**
Balaji Kandadai, Kimberly-Clark	You said you could not measure nip loads less than 10 N/meter. What is the accuracy of the sensor at low tension levels? Film based sensors are time sensitive and would this device, if we were to use this over a long period of time, provide repeatable measurements?

Name & Affiliation	**Answer**
Bob Bettendorf, Metso Paper, USA	I don’t have the specifications with me so I cannot answer your first question regarding the minimum tension that can be measured. With regard to the second question: The sensors are pretty stable with respect to time. The biggest drawback of these sensors is that above approximately 90°C they lose their sensitivity. As long as you keep the operating temperature below that (we run as high as 70°C) we don’t see the charge dissipating. They will last quite a long time.
Name & Affiliation	**Question**
Jerry Brown, Essex Systems	I am curious if this film is proprietary or if it is commercially available?
Name & Affiliation	**Answer**
Bob Bettendorf, Metso Paper, USA	It is commercially available. We did work with the vendor to improve the repeatability of their production to get a custom configuration made for us, but the film can be purchased.
Name & Affiliation	**Question**
Jami Haque, Fife Corporation	When you have a capacitor based sensor that relies on charge, how do the electrostatic discharges affect this system?
Name & Affiliation	**Answer**
Bob Bettendorf, Metso Paper, USA	That is a good question. There is a lot of static built up in web lines in winders. Our sensor is actually a multilayer sensor with some shielding that does prevent noise from getting into the sensor signal, but as far as electrostatic discharge from static buildup, I don’t know how it would affect the sensor.
Name & Affiliation	**Question**
Sam Kidane, 3M Company	In Figure 11 there is a long lag time shown. Is this method useful for making a roll on this system, given the time delay?
Name & Affiliation	**Answer**
Bob Bettendorf, Metso Paper, USA	There is some time delay from the time the control is turned on until it starts having effect. That is primarily due to the actuators employed in the calender zone control roll. These actuators do not respond quickly. That is typical of most profile control actuators used on a paper machine, they tend to have a slow response.
Name & Affiliation	**Question**
Sam Kidane, 3M Company	Could this delay be accounted for in computation to make a good roll?
Name & Affiliation	**Answer**
Bob Bettendorf, Metso Paper, USA	First of all there are actuators with even more lag than those employed here. That is independent of the intelligent roll. The intelligent roll samples at 10,000 Hz and thus the signal is updated pretty fast, it is the mechanical actuators that are comparatively slow.

Name & Affiliation	Question
Bob Lucas, Winder Science	It will take time for you to reach temperature equilibrium in the nip as well which is also a component of the delay. When the nip profile is changed it will affect temperature. This can require considerable time to settle out.