

TEMPERATURE PROFILE MEASUREMENT APPLICATIONS OF MOVING WEBS AND ROLL STRUCTURES WITH INTELLIGENT ROLL EMBEDDED SENSOR TECHNOLOGY

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SUMMARY

An intelligent roll for sheet and roll cover temperature profiles is a mechatronic system consisting of a roll in a web handling machine that is also used as a transducer for sensing cross machine profiles. The embedded temperature sensor strips are mounted under or inside the roll cover covering the full width of the roll cross dimensional length. The sensor system provides new possibilities for online temperature measurements by exceptional sensitivity and resolution without adding external measurement devices. The measurement is non-contacting, making it free from various disturbances effecting non-contacting temperature measurements and it is able to show the roll cover internal temperatures. This helps to create applications that have not been possible with traditional technology, offering opportunities in process controls and condition monitoring.

An application used for process analysis services without adding a roll cover is done with “iRoll Portable Temperature” by mounting the sensor on the shell in a helical arrangement by special taping. The “iRoll Temperature” sensors are used for various purposes depending on the application; two main targets being the online temperature profile measurement of moving web and monitoring internal temperatures of roll covers.

The online sheet temperature profile finds its main use in optimising moisture profiles and drying processes enabling the removal of speed and runnability bottlenecks by detecting inadequate drying capacity across the sheet CD width, monitoring the condition of drying equipment, optimising drying energy consumption, preventing un-necessary over drying, optimising float drying of coating colors and detecting reasons for moisture profile errors.

The application can also be used in tissue machines, where the measurement system is embedded on a web guide foil rather than a roll. In tissue machines the sheet temperature profile is a good indication of moisture profile and thus the sensor system provides a cost-efficient alternative to more complex moisture profile measurement arrangements.

Thermal crowning effects of nipped rollers can be managed by using the embedded sensor system. The roll cover internal temperature profile measurement can help to reduce roll maintenance costs and machine downtime. The sensitive measurement helps to prevent cover failures caused by thermal effects or overloading and facilitates optimal cooling water circulation. Another aim is to prevent nip load errors from temperature-related sources, creating more consistent water removal at the press or better parent roll hardness profiles by detecting temperature related calender nip errors.

This paper describes this novel technology and its use in the paper, board and tissue industry, however the application can be extended to pulp drying and also industries outside pulp and paper such as the converting and manufacturing of plastic films.

Keywords: Roll temperature, embedded sensor, temperature control

APPLICATION

It is well known that variations in the temperatures of a web and drying equipment affect drying process efficiency. In the paper making process, temperature profile variations or sub-optimal machine direction control can lead to excess energy consumption, reduced drying capacity, runnability issues and end product profile errors. Drying processes are a critical area for paper making with respect to energy consumption and also the profile uniformity. It is estimated that 20 to 30% of the operating cost in paper making is from energy, either steam or electricity (1). One outcome of this technology is more accurate control of drying in the machine cross dimension, creating an incentive for optimising the drying processes further.

Sheet temperature measurements have been used for process troubleshooting in the paper industry, typically using non-contacting measurement with handheld IR-temperature measurement probes or thermal cameras. These tools are used mostly for supporting maintenance instead of thorough process analysis. Some profile measurement scanners also have temperature measurements, but are less frequently used for demanding profile optimisation, analysis and control. Roll cover overheating prevention with thermal imaging has also been utilised in calender applications for hotspot detection. Non-contacting methods can be effected by in-accuracies such as absorptivity, reflectivity and transmissivity rate variation of the measured material, dirt accumulation on measurement devices, steam, vapors or hot air flows or the person doing the measurement (e.g. the angle of viewing the measured material is important). These issues could be overcome by using a contacting measurement, but the measurement method would need to be free from its specific errors such as friction effect while measuring a moving object such as a Yankee cylinder (2).

When considering pulp and paper industry, the temperature profile measurements are widely utilised in tissue paper making. In production lines where the automation level is lower and moisture profile scanner equipment does not exist, the operators can be detecting moisture profile variation with thermal imaging of the web after Yankee drying or parent roll surface at reel. The sheet temperature profile has been found to be a good indication of moisture profiles and thus telling about press nip profile and Yankee hood drying functioning (3).

Measuring moisture content through temperature is especially interesting in products where the moisture is too low to be detected by using moisture profile measurements. An online tool with properly set accurate cross dimension mapping would bring an easier and more accurate method compared to handheld measurement tools. This kind of equipment would work well for both roll cover protection and in-depth analysis of sheet temperature profiles for process optimisation. One analogy can be found in plastic sheets manufacturing, where pyrometers are utilised in a sophisticated manner to control the thermoforming process. In these applications a thermoplastic sheet is measured with a pyrometer against a radiating field for accurate control of the forming process, which is affected by the material temperature profiles. In this measurement application the result is also affected by the sheet properties such as transparency and surrounding background radiation, which requires compensation for any error (4).

In conclusion, sheet and roll cover temperature profile measurements with high accuracy have potential applications in the pulp and paper industry but the measurement methods must be very robust to avoid errors due to the material being measured or effects from surrounding equipment and dirt. These demands are best overcome using a contacting measurement method, integrated inside the process equipment. Typically, online measurements in the paper industry, for example sheet profile scanners or thermal imaging for roll cover temperatures, have been independent devices at a certain position in the production process. The measurements look at the process, equipment and paper web from “outside” which creates limitations to the use of these systems. Modern measurement sensor technologies are able to embed the measurements and intelligence inside the process and the equipment. These embedded measurements can show deviations and fluctuations with accuracy and sensitivity not possible before. One example of such embedded technology has been the traditional intelligent roll, “iRoll” with its application from wet end to the winding of paper, board and tissue production lines (5-8). These technologies show the benefits of fully embedded measurement system; for example, sensing roller nip load profiles, sheet tension profiles, parent roll hardness profiles and also being used for online profile control applications (9-14).

The latest addition to the intelligent roll technology is the “iRoll Temperature” system, capable of detecting the temperature profile of a moving web or temperature monitoring of roll structures. This technology

incorporates the latest achievements of sensor technology by embedding the measurement system into a roll cover to form a contacting measurement, minimising surrounding sources of errors. Embedded measurement systems are the best solution for protecting roll covers from overheating and condition monitoring for deflection compensated rolls. It can be utilised as a process analysis tool e.g. in improving moisture profiles or optimising drying processes when installed on a web guide roll (18).

Sensing principle

Due to the developments in sensor technology it is now possible to embed advanced sensing components inside structures in the paper making equipment. This paper describes the embedded measurement technology for temperature profiles of moving paper/board/tissue sheets and rotating roll structures - specifically roll covers. The technology uses monolithic temperature sensor integrated circuit elements and allows a contacting temperature profile measurement method to be applied, bringing high sensitivity and resolution, free from disturbances related to contactless methods.

Traditional methods of measuring temperatures have used either:

1. thermometers, e.g. bi-metal or liquid filled glass tubes,
2. electrical probe sensors, e.g. thermocouples, thermistors or thermopiles,
3. contactless methods, e.g. thermal cameras.

Most of the methods demand a lot of space – either restricting the opportunity for embedded measurements or requiring measurement from a distance – creating inaccuracies. The difficulties related to size, electric power consumption and accuracy has been overcome with the electronics industry developing new methods for temperature measurement. One addition to the available methods are the semiconductor probes, which offer the best possibilities for embedded high-resolution sensor structures (15).

A common technology for semiconductor-based sensing is the silicon bandgap temperature sensor. This sensor structure can be embedded in small sized integrated circuits with reasonable cost. Miniature structures on the other hand helps to create sensor structures embedded in structures.

The principle of the sensor is based on the voltage of the base-emitter junction of a BJT, (*bipolar junction transistor*) being temperature-dependent, which can be then utilised for temperature sensing. More advanced designs have been implemented to improve the linearity of the measurement and create more accurate measurements. These advanced designs are used in actual integrated circuits. The typical working principle is PTAT (proportional to absolute temperature), which is using a combination of two BJT or CMOS (*Complementary Metal Oxide Semiconductor*) transistors in combination. The system is based on observing the temperature effects from the difference of base emitter voltage of these two transistors at different current density values. The basic principle of such a system is illustrated in the example circuit diagram below (Figure 1) (16).

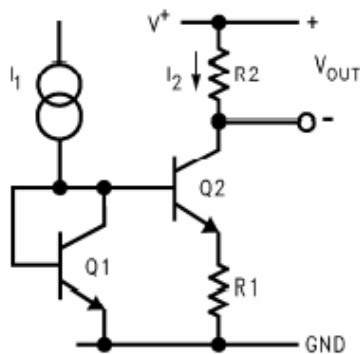


Figure 1 An example of the working principle of an integrated temperature measurement circuit, as presented by Texas Instruments Inc ¹.

¹ AN-460 LM34/LM35 Precision Monolithic Temperature Sensors SNOA748C–October 1986–Revised May 2013, Texas Instruments Incorporated

When both transistors are operating with different emitter current densities (i.e. current / area of the junction), but at the same temperature, the difference of their base emitter voltages V_{out} (or ΔV_{BE} as written below), can be calculated as shown by equation 1 (16):

$$\Delta V_{BE} = V_{BE1} - V_{BE2} = \frac{kT}{q} \ln \frac{J_{E1}}{J_{E2}} \quad (1)$$

In which the k is Boltzman's constant, q is the charge of an electron, T is temperature in Kelvin, and J_{E1} and J_{E2} are emitter current densities of transistors Q_1 and Q_2 . If J_{E1} and J_{E2} are kept constant (as part of the surrounding circuit design), then ΔV_{BE} is a function of temperature utilised in the measurement application (16).

This principle can be employed as part of more complex circuit system including various added components to enhance the linearity, accuracy and the functionality of the sensor circuit, implemented in an integrated circuit package. Typically, the components are integrated and packaged in one housing with connections to supply voltages and outputs. Integrated circuit sensors often implement digital connectivity and can operate as part of a chain serially connected in the same sensor arrangement. The sensors may also incorporate EEPROM memory, processing capabilities, clock and timer circuits to give easy and more accurate operation as part of wider sensor systems (17).

In the intelligent roll temperature measurement application, a series of intelligent sensors are mounted to form a measurement strip which is integrated into a roll cover. The sensor system is built of integrated circuits including the abovementioned digital communicability with high resolution silicone-based bandgap temperature sensors in an array. The implementation principle allows sensor components to be placed in a flexible manner under the roll cover, allowing optimisation of the measurement system for each application - whether the aim is to monitor the roll cover itself or to measure the sheet temperature profile on a web guide roll. The number of circuits in the sensor array is chosen based on the roll dimensions and the desired number of measurement points (i.e. databoxes) in the profile. All signal transfers are digital, so the measurement is free from noise.

Implementation of "iRoll Temperature"

An intelligent roll for sheet and roll cover temperature profiles is a mechatronic system consisting of a roll in a web handling machine that is also used as a transducer for sensing cross machine profiles. The "iRoll Temperature" measures temperature CD profiles and MD trends online with embedded temperature sensor strips mounted under or inside roll cover so that they cover the full width of the roll cross dimensional length. The system can be quickly commissioned to measure moving paper web or the roll itself, due to a sensor technology that typically does not require additional calibration. The system is a contacting measurement, not affected by reflections, emission rates, dirt, vapor or hot air flows.

Measurement implementation on a rotating roll enables good thermal contact between sheet and measurement system. There is no need to add scanning measurement equipment in the production line layout and no regular need for cleaning. Grooving can be added to enhance contact between the sheet and the roll if needed. The profile resolution and measurement speed can be set according to the application up to 50 mm in CD and 30 seconds in MD, temperature resolution of $\pm 0,025^\circ\text{C}$, maximum temperature level of 150°C . The technology can operate on rotating rolls or stationary web guide foils and it can be linked to online controls. The intelligent roll consists of a high-precision roll body with temperature sensors, roll covers, signal processing electronics, a digital radio transmitter, battery or wireless power transmission, and a receiver providing the data onwards to a PC with monitors, automation systems or Industrial Internet platforms (19). Figure 2 illustrates the construction of an intelligent roll. Figure 3 illustrates the software tools for transferring and analysing the profile data.

The contacting sensor system provides new possibilities for online temperature measurements by exceptional sensitivity and resolution. This helps to create applications that have not been possible with traditional technology, with opportunities in process controls and condition monitoring. Main application areas for "iRoll Temperature" are temperature measurement of roll structures in condition monitoring and online temperature profile measurement of sheet temperatures for optimised drying and moisture profiles. The system

can be utilised in all paper, board and tissue machines (Figure 4), pulp dryers, offline calenders, coaters and industries outside pulp and paper such as converting lines and plastics films production.

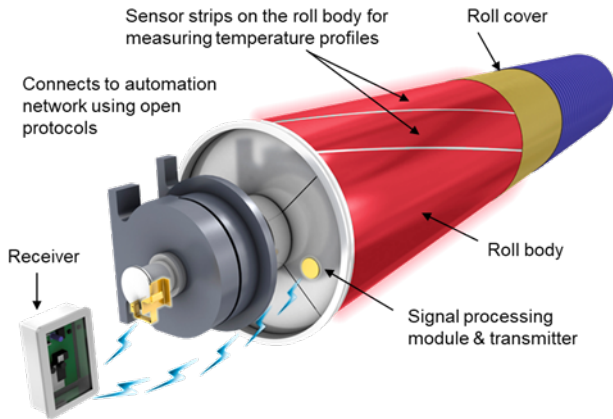


Figure 2. The intelligent roll and its components (19).

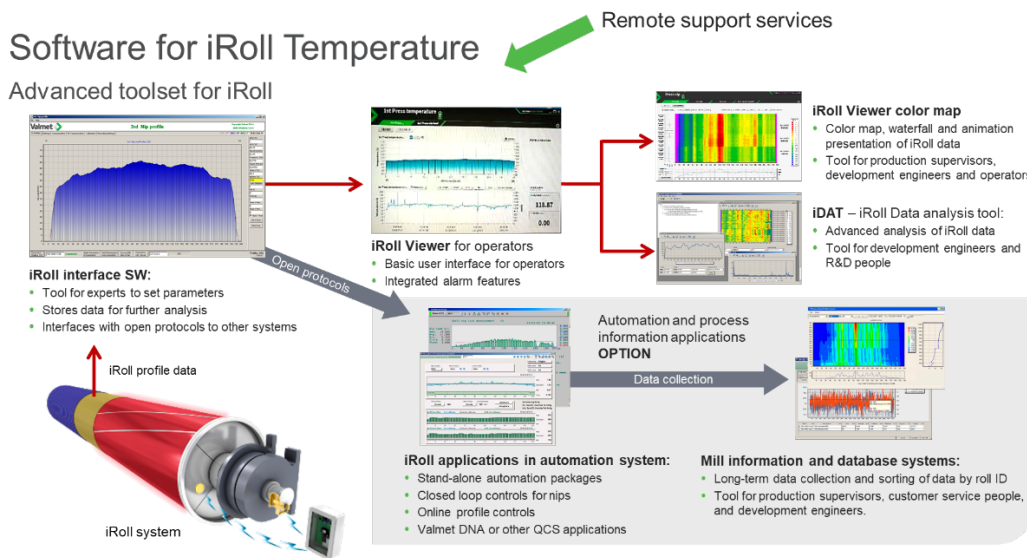


Figure 3. Software tools for accessing and using the data.

- **iRoll temperature measurements:**
 - Press roll covers
 - Sizer and coater covers
 - Soft calender covers
 - Web guide foils (esp. tissue machines)
 - Reel and winder covers
 - Fabric or paper guide roll covers
 - iRoll portable technology: temporary system for temperature profile analysis, drying and profiling equipment optimization

- Available for all polymer roll covers:
 - Rubber, polyurethane, composite
 - iRoll portable technology also available for non-covered rolls
 - Stationary equipment also possible

Figure 4. Applications in various roll cover positions and cover materials.

Internal roll cover temperature profile measurement can help to reduce roll maintenance costs and machine downtime. The sensitive measurement helps to prevent cover failures caused by thermal effects or overloading and enables adjustment for optimal cooling water circulation. One benefit is also preventing nip load errors from temperature-related sources leading to more consistent water removal at the press or better parent roll hardness profiles and sheet quality by detecting temperature related calender nip errors. Thermal crowning effects of nipped rollers can also be managed by using the embedded sensor system.

An example use case roll cover temperature and condition monitoring is illustrated in figure 5. In this example, measurements show that tip load conditions of a deflection-compensated roll is changing due to temperature effects. On the right of figure 5, the drive side, the roll is overloaded due to the internal oil temperature creeping higher after each machine start-up. This presents the risk of cover failure. Simultaneous online nip load and temperature profile measurements reveal the loading peaks and temperature creeping. Using the online temperature profile measurement, the exact source of the problem can be pinpointed by analysing the data while still in production. A similar approach can be taken to water-cooled rolls to avoid loading/temperature issues from limestone build-up or water circulation issues.

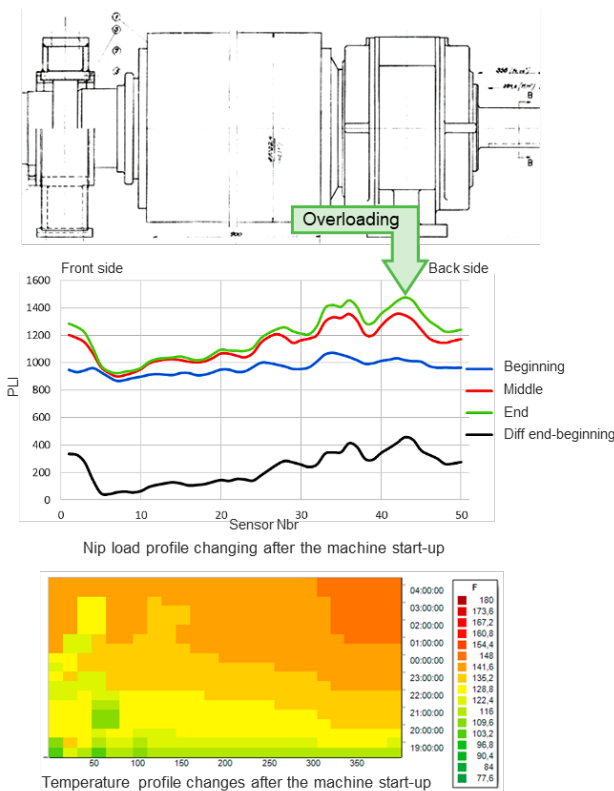


Figure 5. Example of roll cover temperature and condition monitoring.

The online sheet temperature profile demonstrates its biggest value when optimising moisture profiles and drying processes, removing speed and runnability bottlenecks by detecting inadequate drying capacity across the sheet CD width, monitoring condition of drying equipment, optimising drying energy consumption, preventing un-necessary over drying and detecting reasons for moisture profile errors. An important subcategory is the drying in coating processes, leading to optimal power on each float dryer drying unit,

adjusting dryers with profiling capability, preventing overheating of sensitive coating colors such as thermal or barrier coatings and ensuring adequate temperatures for curing silicone coatings.

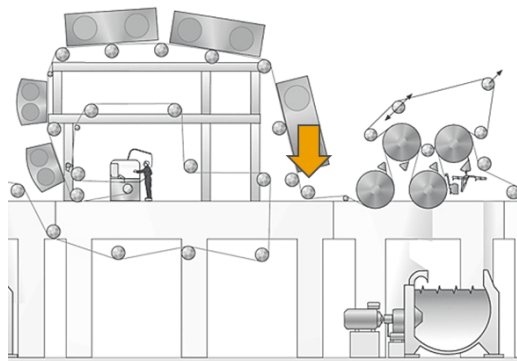
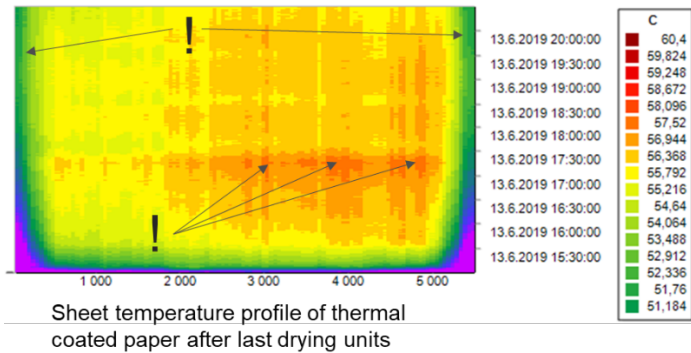


Figure 6. Example of sheet temperature profile monitoring on a temperature critical coating process with maximum allowed temperature.

An example of the use of sheet temperature monitoring with thermal or barrier coatings is illustrated in figure 6. In this case, measurements located on a web guide roll after the last air dryer unit shows the variation of sheet temperatures over time and also across the CD width of the sheet. The data reveals that the 60°C maximum temperature limit of the thermal coating color is in danger of being exceeded in the hottest spots. Conversely, cool areas, especially on edges, show the need to add more drying power there, lowering the risk of wet coating stripes. Setting alarms when temperature limits are exceeded in any CD area of the sheet, optimising the drying process for more uniform temperature profile, eliminating speed bottlenecks and avoiding broke can be benefits of high-resolution temperature measurement in this case.

The technology can also be used in tissue machines, in which the measurement system is embedded on a web guide foil rather than a roll. In tissue machines the sheet temperature profile is a good indication of moisture profile and thus the sensor system provides a cost-efficient alternative to more complex moisture profile measurement arrangements. Optimising Yankee cylinder hood drying is also one application in tissue making.

Various applications and targets has been identified in the paper and board making process. These applications can also expanded where applicable to tissue making and pulp drying. Figure 7 illustrates possible areas of application in paper/board machine wet, drying section and film sizing equipment. Figure 8 illustrates the corresponding possibilities in the finishing section and dry end.

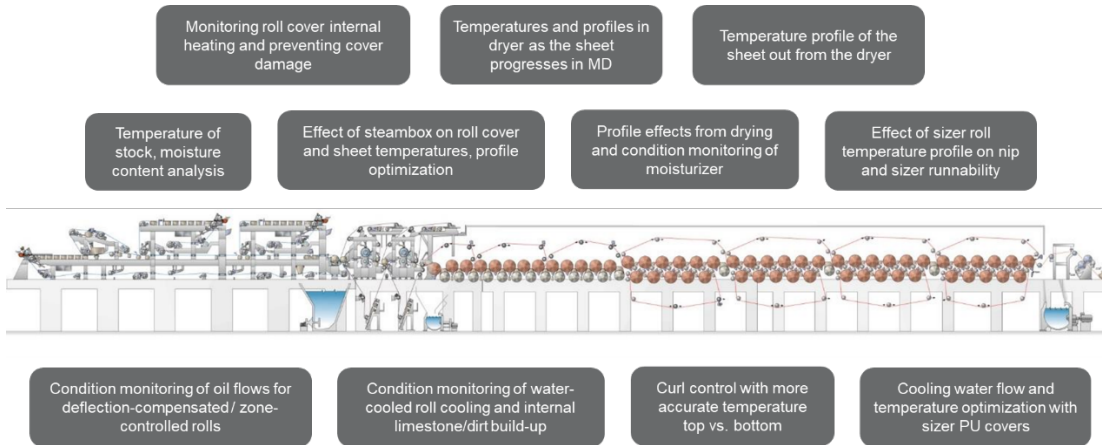


Figure 7. Examples of utilisation on board machine wet end, drying and film sizing.

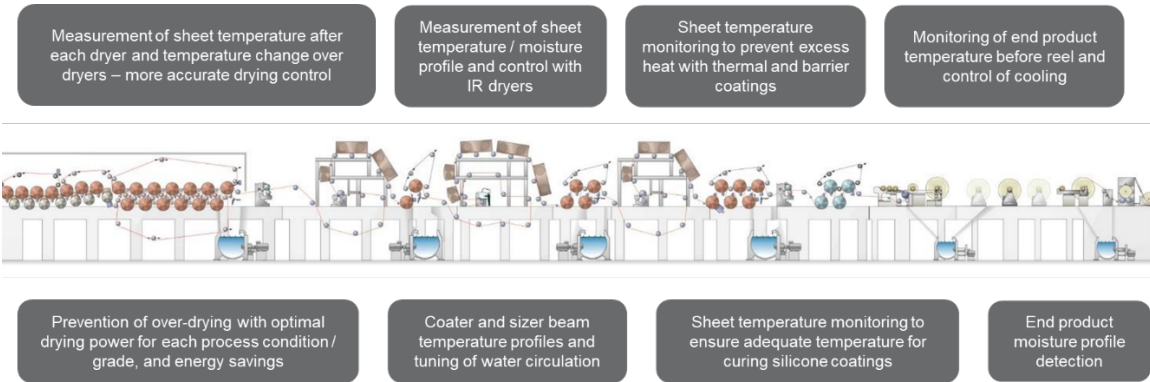


Figure 8. Examples of utilisation on board machine finishing equipment and dry end.

One application used for process analysis services without adding a roll cover is achieved with “iRoll Portable Temperature” by mounting the sensor on the shell in a helical arrangement using special tape (Figure 9).

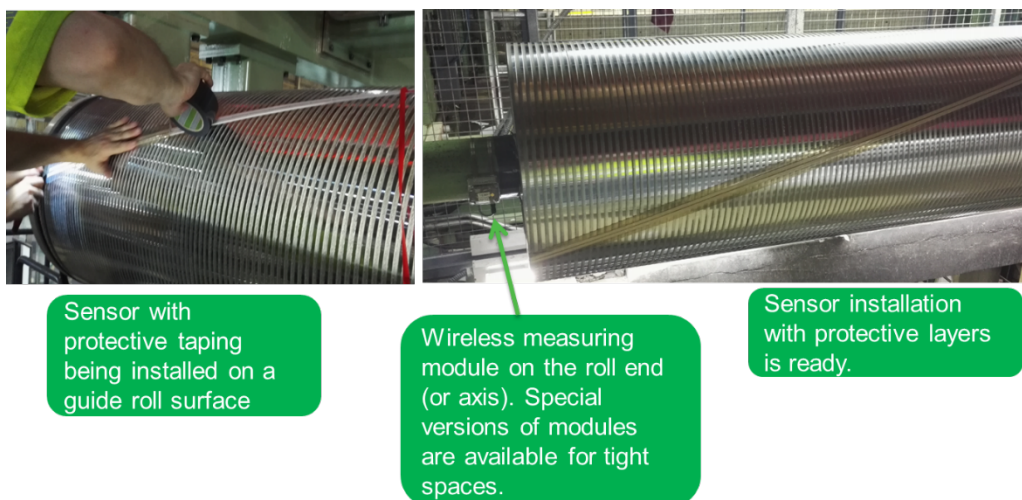


Figure 9. Installation of sheet temperature profile measurement system with “iRoll Portable” technology. This version of the measurement technology enables online process analysis and troubleshooting using temporary, installed sheet temperature profile measurement. The sensors can be mounted on several

interesting roll positions at the same time and used for optimising several drying states simultaneously. Other targets for temperature profile measurements are: solving moisture profile errors or analysing sheet induced “temperature crowning” effects at calender nips.

THREE CASE STUDIES OF INTELLIGENT ROLL TEMPERATURE PROFILE MEASUREMENT

Case Study 1. Troubleshooting of roll cover failures

A carton board producer was experiencing constant roll cover failures at their smoothing press. These failures occurred with both rubber and polyurethane covers, typically on the front side of the machine, some across wider areas. Loading conditions were fairly mild, with nip loads up to 65kN/m and speeds up to 800m/min. Temperatures were considered relatively low when measured with thermal imaging or manual IR devices. Under these conditions there should not have been issues with roll covers.

To find out the reasons for roll cover damage, an iRoll system was applied including both nip load and temperature profile sensors embedded inside the cover. The embedded measurement system revealed immediately that the temperatures inside the roll cover could reach almost 120°C, while lower values were measured on the surface. During the highest temperature peaks the temperature profile shape also changed, with the front side half of the CD width being hottest and exceeding the cover maximum allowed temperature (Figure 10). These findings were consistent with cover damage, despite all observations made on the outside of the roll showing no reason for the failure. When analysing the data, it was found that the behavior had been systematic. When the average temperature exceeded 112°C, temperature profiles became skewed.

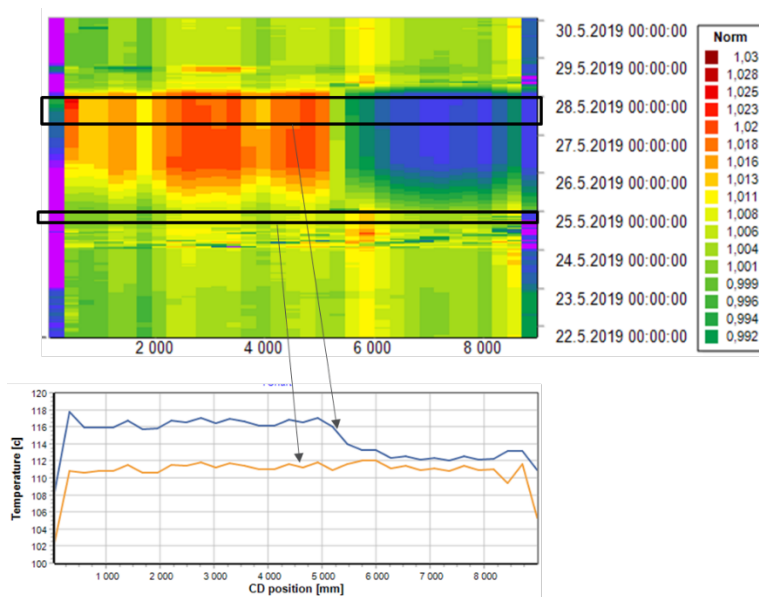


Figure 10. Temperature profiles inside the roll cover. The color map shows the profiles in normalised format with the lower graph in Centigrade. The problematic increase of temperatures on one side of the roll is shown clearly.

The nip load profile data was also analysed to see if it could explain the elevation of temperatures. As the roll covers create heat in dynamic conditions due to internal friction, it was expected that the highest temperature would be observed when the nip loading was at its highest, but the reality was to the contrary. When plotting a machine direction average trend of the nip loads it was revealed that the temperature decreased when nip load increased. Sheet temperature was measured before and after the smoothing press nip. The sheet had higher temperature after the nip, so the sheet was taking away thermal energy from the nip. The reason for the temperature increase could have been due to speed difference causing slippage, but drive speeds seemed to be ok.

The nip load and temperature profiles gave more information (Figure 11): the lowest nip load area on the front quarter seemed to heat up the most and more highly loaded areas on the back side ran cooler. This could be explained by higher loading enabling better heat transfer from the roll cover to the sheet and thus cooling it. On the other hand, the low loading area on the front quarter could have some slippage generating more heat inside the cover when the overall temperature was elevated. These findings could explain the odd nip load and temperature profile relation and the position of the failures in the cross dimension. But the reason for overall heat elevation needed to be determined definitively.

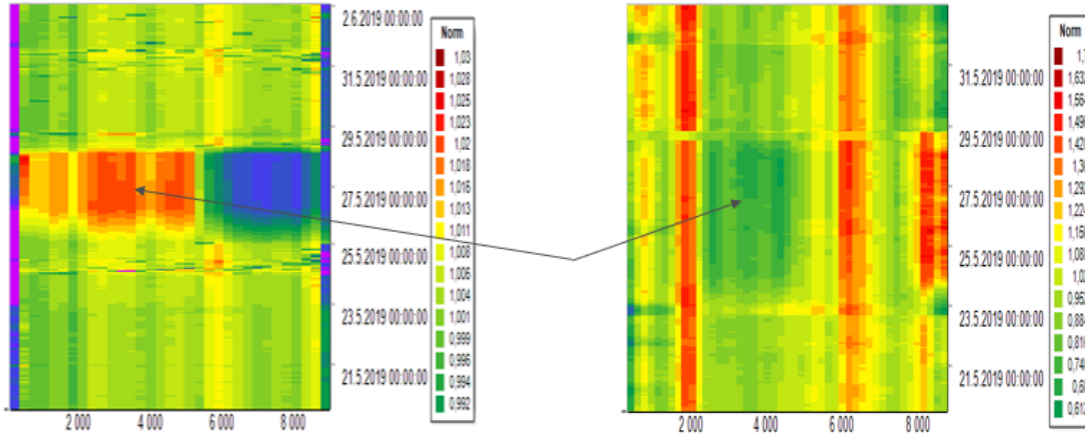


Figure 11. Nip load (left) and temperature profile (right) during a period with elevated roll cover temperature. Both profile data sets are illustrated in normalised format.

With further analysis of the data, it was noticed that the temperature inside the cover correlated with speed – the higher the speed, the higher the temperature but lower the nip load (Figure 12). The problematic roll was partially filled with a water glycol mixture, but there was no circulation to rotate the mix in and out of the roll. Thus, the roll was running cool when measured on the surface, but still running hot on the shell/inside the cover. The water glycol mixture was not helping at all as the temperature profile was uneven. The surface of the roll showed clearly lower temperatures and the sheet was actually cooling the cover. Roll cover heat generation due to internal friction could not be the problem as the heat was highest with the lowest loading levels.

The only conclusion left, after studying the data was that the water glycol mix inside the roll and its amount, was causing heat generation due to the viscosity of the liquid. This would explain why the faster the machine ran, the more heat was generated inside the roll. At the same time small degrees of slippage

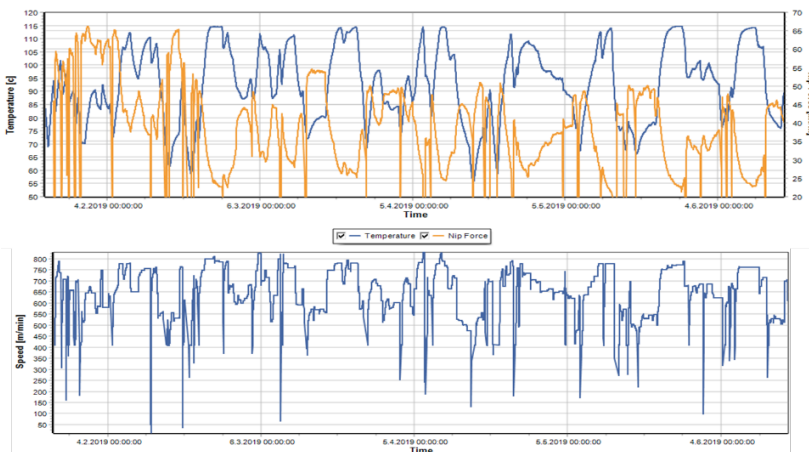


Figure 12. Machine direction trends of roll cover internal temperature, nip load and machine speed.

on the lowest loaded area in the CD profile was causing the cover maximum temperature to be locally exceeded leading to cover failure.

As an immediate aid to cool the cover down the internal water was opened to atmosphere to reduce its maximum pressure. Thus the temperature was also reduced to atmospheric boiling point instead of reaching almost 120°C, staying well under the roll cover maximum operating temperature. As a longer-term cure, a small water circulation loop is to be installed to provide additional cooling. iRoll Temperature and nip profile measurements were recommended for regular use to observe the temperatures and to prevent loading conditions that could induce local slippage. Since these actions were taken the roll cover failures have been avoided.



Figure 13. Wrinkle problem on parent roll surface.

Case Study 2. Using sheet temperature measurement to solve calender profile issues

A packaging board production line was experiencing corrugations and wrinkles in parent rolls, causing an excessive amount of broke at the winder (Figure 13). The profile errors occurred with calendered grades whereas non-calendered were mainly good. Certain areas near the drive side were causing most of the issues. QCS measurements were not showing any clear reason for the wrinkle problems so, clearly, some factor outside the “traditional” profile measurements was having an effect.

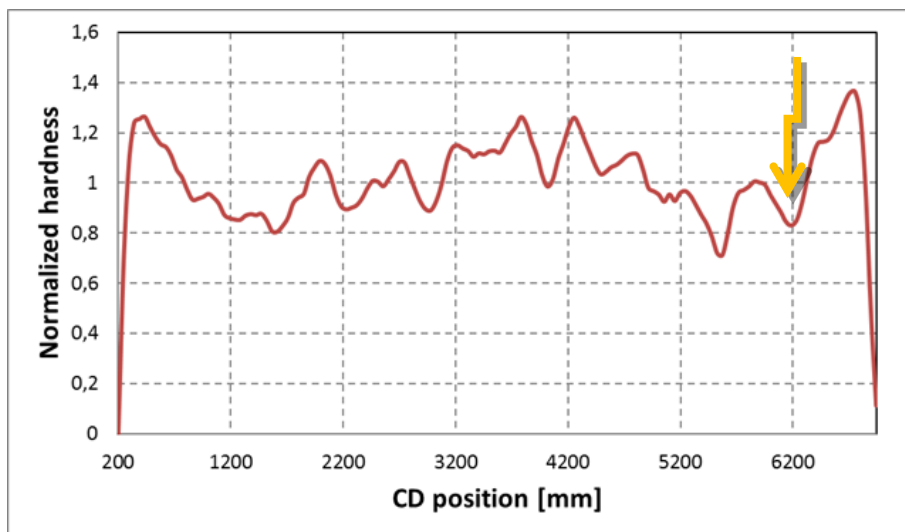


Figure 14. Hardness profile measured with iRoll system at the winder. The worst wrinkles occurred on the soft area next to a hard edge – the biggest profile gradient.

To bring new additional information and insight, iRoll measurements were utilised to analyse the problem. The aim of this work was to find out how to tune up the calender and other processes to improve profiles. The measurements consisted of: parent roll hardness profiles with an iRoll system at the winder and tension profile measurement before & after the calenders with a sheet temperature profile after calender as it is important to see what the calender temperature profile is causing to the other profiles.

Hardness profile gradient (Figure 14) especially at the drive side edge was found to correlate with the wrinkles and this happened in connection with calendering as it did not occur with non-calendered grades. However, the calender itself did not seem to have any issues and was in good condition. Tension profile measurements were also showing related profile variation. Other profile measurements (moisture, dry weight, calender nip profile settings...) did not show anything out of the ordinary. The sheet temperature profile data was evaluated in order to see if that could be causing issues while calendering.

Hardness and temperature profiles were compared and found to have a negative correlation (Figure 15). The high temperature areas apparently having high nip load in the calender nip and becoming low in caliper/hardness and vice versa.

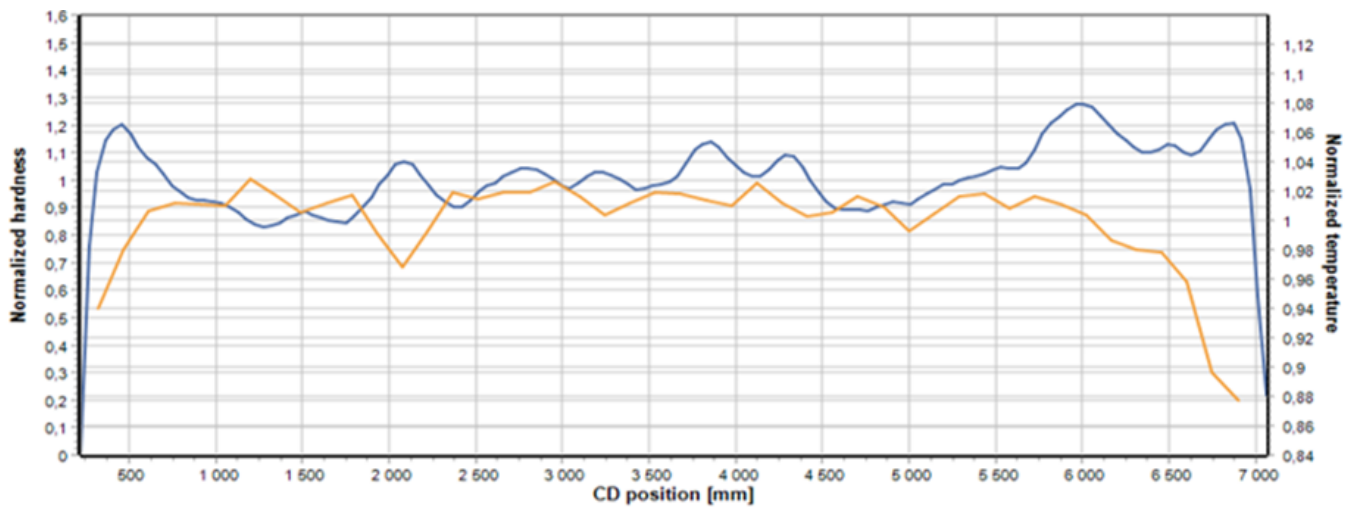


Figure 15. Hardness profile (blue graph) measured with iRoll system at winder compared to sheet temperature profile (orange graph) at calender.

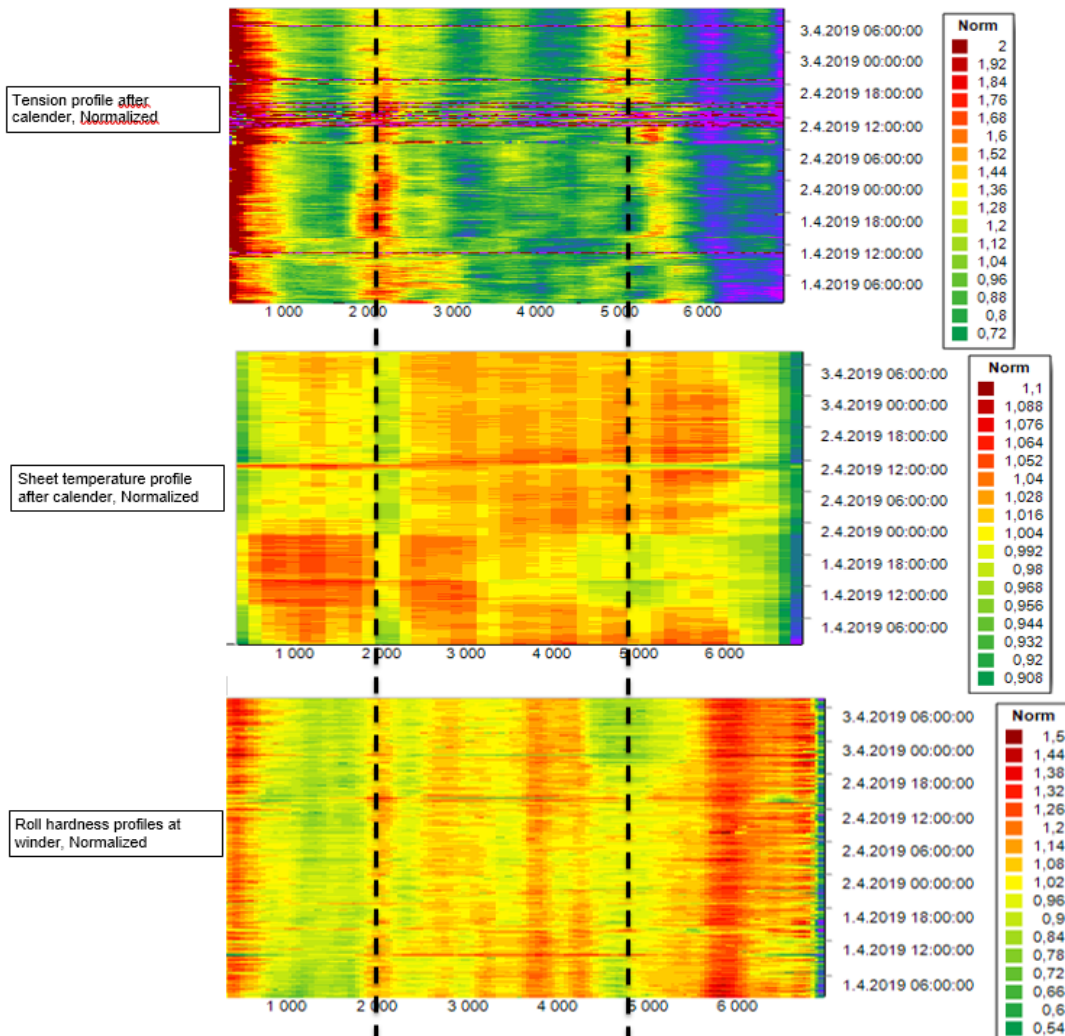


Figure 16. Web tension profile, sheet temperature profile and hardness profile in normalised color map format.

Some corresponding shapes could be seen in the tension profiles before and after the calender (Figure 16). As a result it was concluded that the temperature profile from the sheet was reproduced at the calender nips and caused hardness profile errors through “thermal profiling”.

The sheet temperature profile can be affected by several factors, e.g. a combination of drying cylinder and fabric wearing/cleanliness, sizer starch application, hood ventilation, air flows on various stages and the calender itself. These factors are complex, hard to manage and will fluctuate over time. Thus, air cooling blows were used as a first attempt to moderate the biggest temperature errors. Another strategy was to improve the hard edges by changing the calender nip deflection compensated roll settings. As a long-term solution an online thermal profiler was recommended for the calender to stabilise and improve the profiles with automatic control.

Case Study 3. Using iRoll Temperature portable technology to improve sizer runnability and profiles

A liner board production line had runnability difficulties at its sizer. Due to the web handling issues the sizer nip load was limited – reducing starch application efficiency due to the constrained and lower nip peak pressure. Increasing nip load led to wrinkling and production losses. Several factors were affecting the problem as individual corrective action had not been of help. To study the reasons and possible improvements for the problem iRoll Portable technology was employed. The study included tension profile measurement before the sizer – revealing incoming sheet characteristics which are often the cause of runnability issues - loose web edges. At another position a dynamic sizer nip load profile measurement with iRoll Portable system was included to optimise the nip loading conditions and to observe whether the roll cover crowning could be updated. At a third position a sheet temperature profile measurement was implemented to observe how the sheet exited the drying section and to compare this to all other QCS profiles. This comparison was considered important as moisture profile errors had been observed earlier. Press nip profiles were also checked with dynamic iRoll Portable measurement to check their impact on the moisture profiles and sheet tension profile properties.

The dynamic nip profile measurement revealed that the sizer nip control was difficult to maintain and often ended up being skewed. The skewness was generated by the rod applicator beam that skewed the nip despite it being symmetric before loading. Tests with various nip loading levels and beam loading parameters were undertaken and suitable loading settings were obtained for the sizer. The effect of beam loading could be compensated based on the loading trial results. Also, alignment actions were recommended. This gave some improvement but still the web seemed to be somewhat unstable especially on the tending side.

Tension profile measurement during production revealed that the sheet tending side edge often had a slack area. Earlier findings of moisture profile errors on this same area did have some correlation with the tension profile issue. Dynamic press nip profile measurement data was examined and there were some improvement found to enhance the nip dewatering on the 1st press, but those could not be related to the loose edge. The unstable loose edge was causing increased wrinkling tendency, in addition to the sizer nip load conditions, so it was also deemed a significant factor.

Analysis was continued by focusing on the iRoll Portable sheet temperature profile measurement. This measurement revealed a cool area on the loose tension profile spot, matching with the moisture profile errors, however, hand, press nip profiles or observations from QCS system (dry weight, head box profiling...) did not explain the cool area. As a result it was believed that the cool sheet edge was being caused by the drying section instead. During the study, drying cylinder spoiler bars were found to be misplaced on the tending side and provided the best explanation for the cool, moist, loose sheet edge. The bars needed to be adjusted or replaced.

As a result of using several profile measurements, either dynamic nip profile or online sheet profile measurements with iRoll Portable, the factors affecting the sizer runnability could be analysed and improvements listed. A systematic approach using online data in addition to observations during production showed excellent potential in tackling a complex problem. Figure 17 illustrates the loose sheet edge problem and the measurement positions for analysis and examples of data sets used in the problem solving.

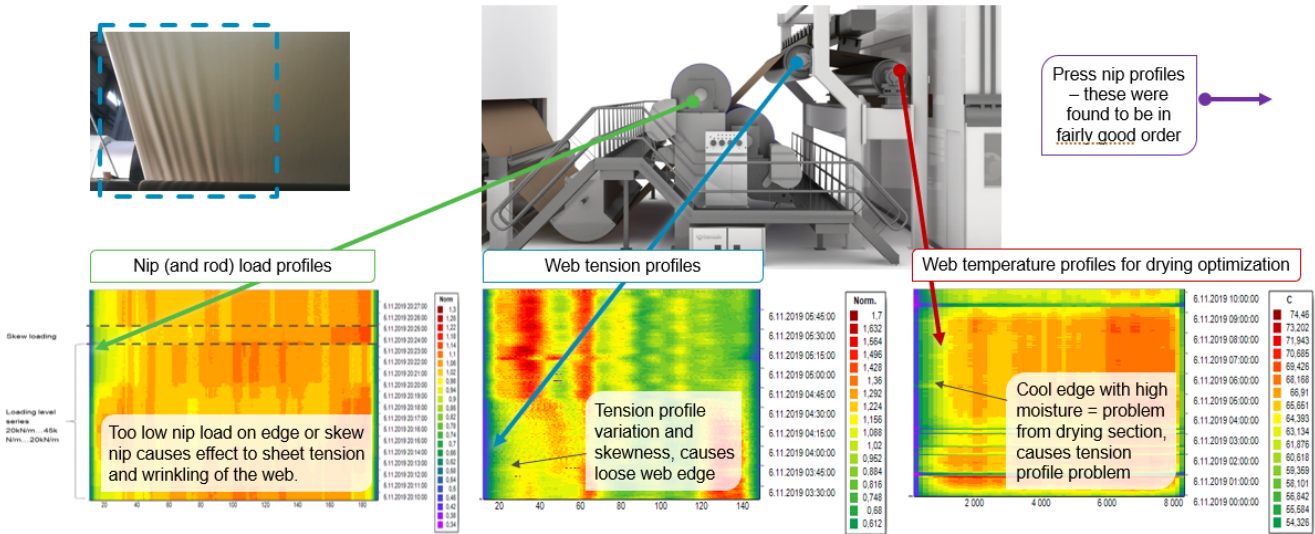


Figure 17. Loose sheet edge at sizer and corresponding profile measurements.

CONCLUSION

This paper presented a novel integrated sheet and roll cover temperature profile measurement system based on developments in integrated circuit based, monolithic, high resolution temperature sensing technology. This intelligent roll temperature profile measurement system turns the roll into a sensor that can be located in place of a conventional roll in a web handling process. The roll can then be used for condition monitoring of roll structures, especially roll covers. It can also be used as a contacting sheet temperature profile measurement to optimise drying processes and improve moisture profiles. In addition, a portable version of the measurement system can be installed temporarily to troubleshoot drying, runnability or moisture profile related problems on a process line.

Three case studies were presented showing the use of the intelligent roll in actual web handling lines. In one case study the system was used successfully to solve problems with roll cover failures. In another application, the system was used to remove reeling and winding broke by improving calender operation and temperature profiles. In the last case, the portable version of the system was used to identify and correct the causes of runnability related bottlenecks in the film sizer area, caused by a loose sheet edge and drying cylinder issues. Besides these examples, a wide range of opportunity was also discussed in the paper with application to paper, board and tissue production lines. These opportunities provide new expansion areas and future development targets for this “iRoll Temperature” technology.

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