WEB INSTABILITY AT OPEN DRAW AND ITS IMPACT ON PAPER MACHINE EFFICIENCY

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ABSTRACT

Paper machine efficiency is mostly affected by machine down time, resulting from maintenance work and web breaks. One of the main factors affecting breaks is the web instability at open draws on paper machines, especially at the wet-end between last press roll and dryer section. Web instability at the open draws can originate from different sources, from web properties variations to machine equipment to pulp quality. Often, the root cause of the instability can be difficult to identify because of the lack of information or tools that could help to understand the relation linking web instability to paper breaks and paper machine efficiency.

Some studies in the literature have shown the importance of reducing paper properties and machine variability at the open draw to maintain good runnability and reduce breaks. Although many studies or specifically developed equipment have aimed at understanding and improving web runnability at the open draw, the means can be either too costly or too complex for papermakers. Hence, the development of accessible, simple and affordable tools to monitor and characterize open draw stability became of high interest. One of the objectives of the work presented in this paper is to actually quantify the open draw stability through some key parameters identified as such in the literature: release angle, paper solids and draw variations.

There are probably additional parameters that will affect open draw stability, but we have decided to focus first on these ones and see if lower variability of release angle, paper solids and draw variations would contribute to fewer web breaks and better machine runnability. Empirical studies completed in paper mills are presented to assess variability of these key parameters at different types of open draws. When possible, links could be made between reduced variability at open draws and the amount of web breaks following these changes.

NOMENCLATURE

cm	centimeter

μm	micrometers
m	distance between position sensor and web (μm)
m_o	initial distance between position sensor and web (μm)
L	Longest web length between two rolls of open draw (cm)
l	length of web at open draw (cm)
θ	Release angle (degrees)
R	Press roll radius
CCD	Charge couple device
CD	Cross direction
MD	Machine direction

INTRODUCTION

Conventional ways to improve paper machine runnability are to monitor and control wet and dry web strength, or to have paper machine upgrades. The former entails the use of chemicals and/or stronger pulps. The latter involves having to rely on equipment suppliers and consultants. In any case, both are costly, and do not always work. Web break is a complex phenomenon and often a multi factorial problem. It is well documented that open draw stability is the main limitation factor for increasing machine speed [1-7]. Increasing the machine speed typically results in an increased amount of breaks at the various open draws throughout the paper machine (couch, presses, size presses, coater, etc.).

One way around the issue brought by open draws consisted in finding solutions to eliminate them, through the design of systems that would maintain the web supported throughout the open draws. In 1991, PAPRICAN researchers developed an experimental wet web transfer system that showed a potential for making a newsprint machine with complete web support from the headbox to the calender [1]. In a similar manner, Albany International came out with another system called TRANSBELT™, a transfer belt along with a special transfer suction roll that gave the possibility to totally close the open draws in the press section and between the press and the dryer section [2]. Such systems to close open draw undoubtedly required major investments from paper producers, and may not have been suitable for all existing machines. As well, it did not address open draws after the dryer sections (at size presses or coaters for example). Therefore, for many papermakers, the open draw stability still remained an issue.

Studying web behavior at open draws is not new, and has been done in many ways. In 1985, researchers at PAPRICAN studied the release behavior of the web from a press roll at the open draw, on their pilot paper machine. Measurements were made of the web tension and release angle with changes in several parameters such as press load, furnish, BW, machine speed, press roll material and web properties. These changes in operating conditions did not strongly affect the work of web separation from the press roll. Ultimately, it was determined that adhesion (or release) tests were difficult to perform reliably and reproducibly [3]. More recently in 2003, KCL developed AHMA, a pilot scale unit meant for measuring tensile directly on the running web, with a one-meter long special test draw section in which breaks happen 'on-line', as the running paper web goes through the open draw. One of the studies with AHMA showed that raising the content of reinforcement pulp from 30% to 50% resulted in a clear increase in the mean strength of paper; however it also increased the variability in strength values, which led to more web breaks. This led to the conclusion that strength uniformity is also critical for web breaks at the open draw [4, 5]. More recently, work conducted by FPInnovations on strength uniformity came to similar findings [6]. Very recently, Edvardsson and Uesaka used the particle approach and developed a novel flexible model to investigate the system dynamics of the open-draw section. The model allowed studying the effect of variations in mass density, elastic stiffness, paper thickness, draw, etc. This work confirmed the critical importance of the release point and its sensitivity to both system and material variations, for example moisture and draw variations [7].

These studies showed the importance of reducing paper properties and machine variability at the open draw to maintain good runnability and reduce breaks. Although many studies or specifically developed equipment have aimed at understanding and improving web runnability at the open draw, the means can be either too costly or too complex for papermakers. Hence, the development of accessible, simple and affordable tools to monitor and characterize open draw stability became of high interest. The objective of the work presented in this paper is to actually quantify the open draw stability through some key parameters identified as such in the literature: release angle, paper solids and draw variations. There are probably other parameters that will affect open draw stability, but we have decided to focus first on these ones and see if lower variability of these parameters would contribute to fewer breaks and better machine runnability. The work presented later in this article is based on this premise. Measurements and analyses were conducted on a variety of paper machines at different types of open draws.

METHODOLOGY

Some of the work outlined in this report was conducted in conjunction with paper mills that had runnability and web breaks issues on their paper machines. Each mill provided data and information, involved their production crews and made changes on their paper machines according to the key findings found through measurements and analysis. For each paper machine studied, measurements with specialized tools developed for the aim of this project were carried out as well as the analysis of the web variability, through the data obtained with the tools set. Ultimately in some cases, we were able to improve the web stability of given open draws, and actually quantify improvements in paper machine runnability (and web breaks reduction). Different tools were developed to monitor web variability at the open draws, and a description for each follows.

Position Sensor for Release Angle Data

The release angle at the open draw is a calculation using distance measurements obtained with a position sensor. As seen in Figure 1, the sensor measures the distance between its fixed position and a fixed point on the web, near the release point from the press roll. The angle can then be calculated; it is proportional to the distance measured. The distance can therefore equally be used as the main measurement. However, it is the variability (standard deviation) of the signal (distance or calculated angle) that is of interest. The hypothesis is that higher variations in the release angle make for an unstable web and can be associated with higher web break rates at the open draw.

The position sensor is a charge couple device (CCD) long range laser displacement. The sampling was done at a very high resolution (0.5 um) and high accuracy (±0.05%). Figure 1 shows an actual set-up of the sensor during measurement at the open draw on a pilot paper machine.

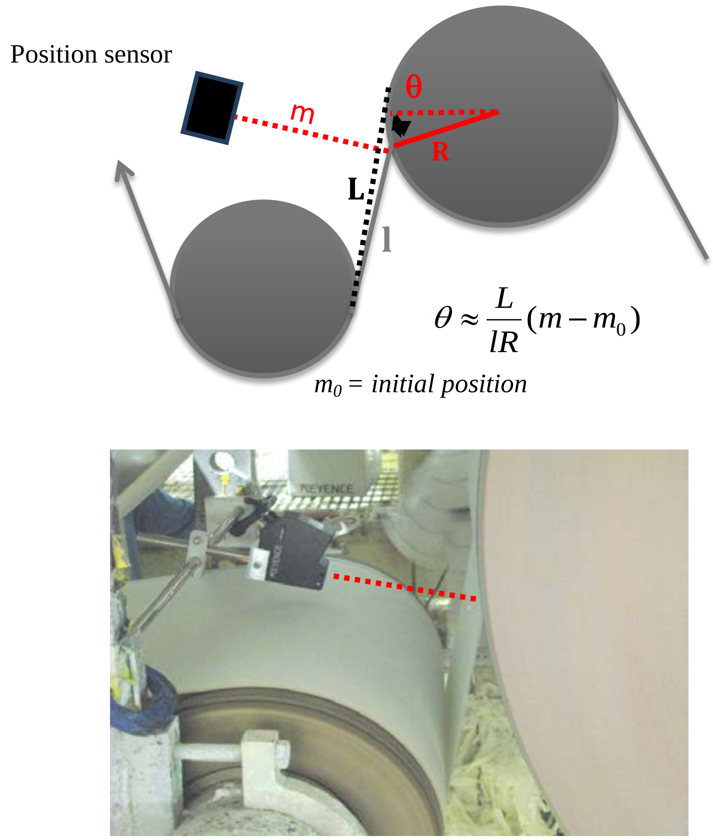
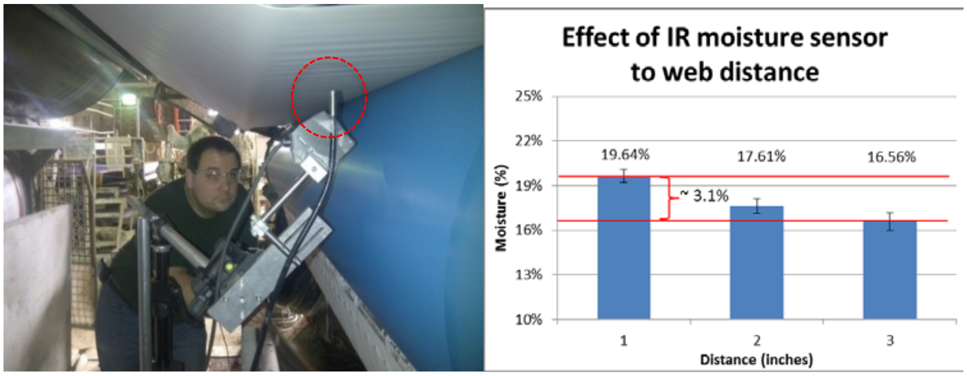


Figure 1 – Schematic of how the release angle is measured and calculated at the open draw and set up of a position sensor at the open draw of a pilot paper machine

Portable IR Solids Content Sensor for Moisture Data

A portable infra-red sensor was used to measure moisture content of the paper. In this study both machine and cross directions have been evaluated for moisture content. The device is a reflecting type in the Z-direction (through the surface layer). There are two specific light bands that are absorbed by moisture: wavelengths of 1.92 µm and 1.45 µm. Adjacent bands of 1.8 µm and 2.1 µm are not affected by moisture and can be used as reference. The ratio between wavelengths is proportional to moisture content in the paper. Sending these signals on the moving web, the altered and non-altered wavelengths are reflected back to the sensor. When compared, the moisture content of the web can be determined. Figure 2 a) shows a set up of the IR moisture sensor at an open draw.

The IR sensor is usually installed at a distance of 1.5 inches from the web surface. However, at the open draws, the sometimes highly floppy webs, or waviness defects would impart significant differences in distance between the sensor and the paper surface. As the reflected signals diminish with increasing distance, this evidently affects the moisture output. As seen in Figure 2 b), a two inch change in distance imparted up to 3% moisture difference in the readings. To eliminate this web gap effect, the CCD sensor (position sensor described above) was placed right next to the moisture sensor. Simultaneous measurements of both distance and moisture allowed determining the linear correction to apply to the moisture data. Distance between the IR sensor and the paper surface was used to correct moisture values.



a) b)

Figure 2 – a) Set up of the portable infra-red moisture sensor at an open draw and b) Effect of distance between IR sensor and paper surface on moisture measurement

Set of Laser Speed Sensors for Web Draw Data

Contactless laser speed sensors were used for measuring the velocity of the web, through the Doppler frequency shift technique. The basis of this technique is that laser light of a known frequency will shift in frequency as it scatters off the surface of a moving material. The velocity is determined by measuring this frequency shift, directly proportional to the velocity of the material. Figure 3 shows the laser speed sensor.

Two sensors are used to simultaneously measure the velocity at two given points on the paper machine (for example before and after a press nip). The data of interest truly becomes the velocity differential between the two points, more commonly called the 'relative draw tension'. As was the case with the other two devices described above, there is a hypothesis that highly variable draw tension will lead to higher break rates. For the purpose of this study, the two measuring points enclose the open draw. For example, sensors would be located before and after the last press, or before and after a size press.

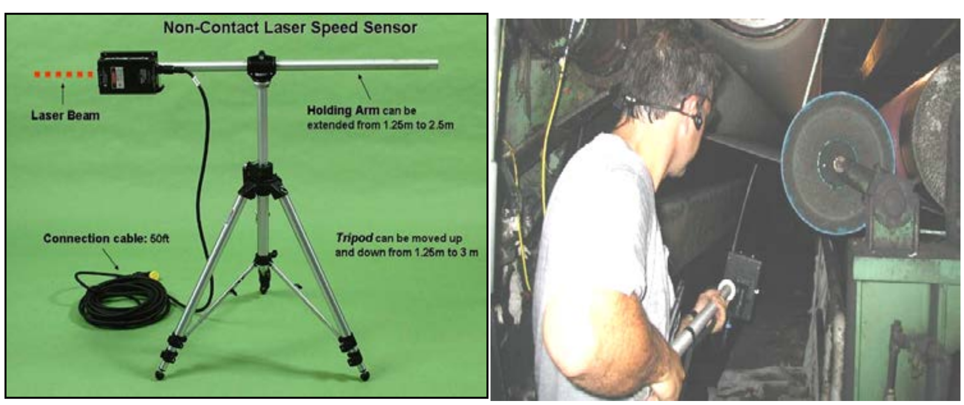


Figure 3 – Non-contact laser speed sensor for velocity measurement

RESULTS

In this section, three case studies are presented to illustrate how the non-uniformity of the web variability and uniformity at open draws and allow identifying specific changes to improve paper machine efficiency and reduce web breaks. The tools are also shown to be useful to confirm the benefits of a change, which is always reassuring to papermakers, as not all changes made can always be linked to improvements at open draw stability.

It is important to note that there is no established procedure when troubleshooting paper machine runnability at open draws. Each mill will usually have a case of its own. The tool set provided can be used to troubleshoot one's issues. The main objective of this empirical study was to quantify open draw stability in term of moisture, release angle and draw variations, and then evaluate if links could be made with web breaks and machine runnability.

Case Study 1:

This case study was carried out on a pilot paper machine and was particularly relevant to the assessment of the position sensor data and draw vs. web breaks. During a run producing newsprint, the draw at the open draw was set at a constant of 2.0%. During this period, the sheet broke twice. Figure 4 shows the fluctuations in release point, in moisture and in draw for a 5 minute period that includes the two paper breaks, and also compares the same parameters with a good runnability time frame. During the period when breaks occurred, there were clearly significant variations in web fluctuations as indicated by the web position sensor, while hardly any during the no-break period. At the same time, the 4th felt speed was showing similar variations. The fluctuation in the speed induced draw variations at the open draw and therefore significant release angle variations and eventually web breaks. Moisture content was uniform with no fluctuation (Figure 4) that could be related to the web instability. It was not possible to link moisture MD variations to release or draw variations.

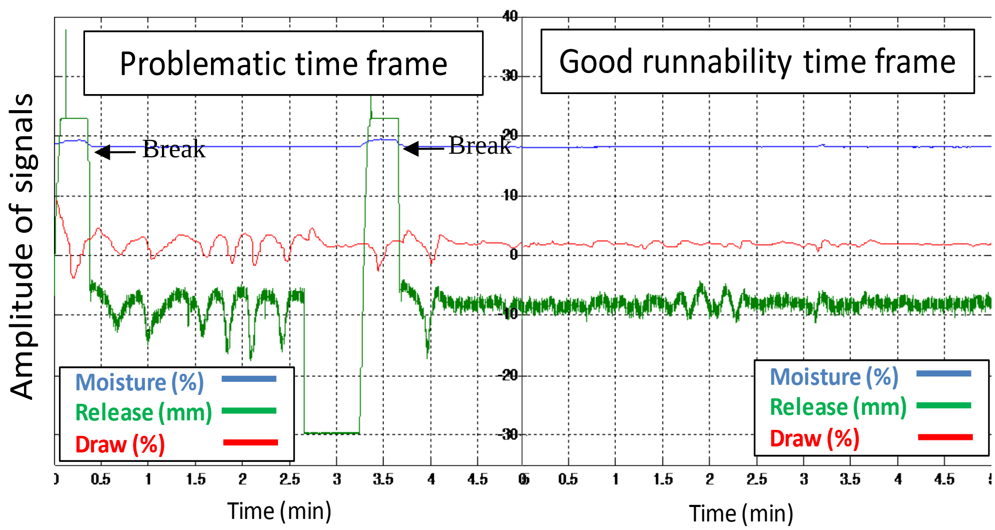


Figure 4 – Release, moisture and felt draw on pilot paper machine

When conducting a frequency analysis on the release angle data (Figure 5), a cycle corresponding to a vacuum suction box could be found. This variation in the vacuum affected the 4th press felt speed (and draw) and therefore the release point at the open draw. This is an example showing how the data obtained with the different sensors can provide comprehensive insight on the open draw stability and web breaks analysis.

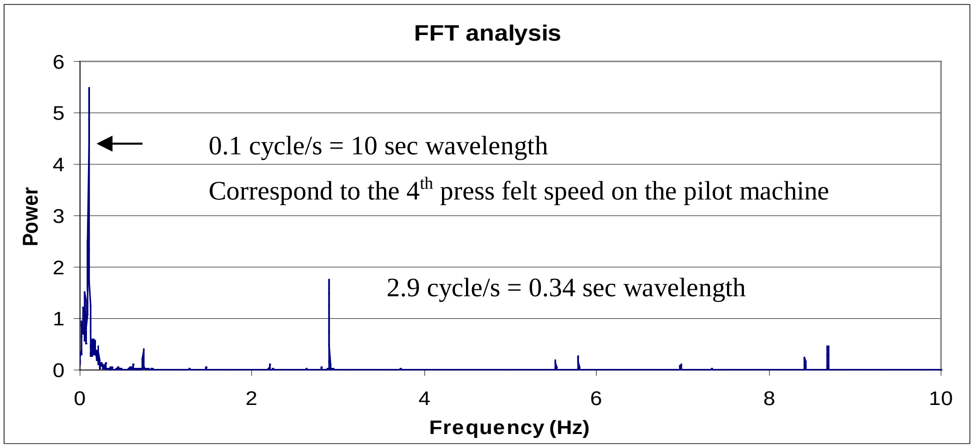


Figure 5 – Frequency analysis of release angle measurement

Another test was carried on the same pilot paper machine to evaluate the impact of increasing draw tension at an open draw on variability of the release angle just before a break. The release angle was measured at several open draw tensions, ranging between 2% and 6%, while producing reinforced newsprint. Figure 6 shows the time trends for two draw conditions, the first one at 5% and the other one just before the web became unstable at the open draw (5.5%). At 5.5% draw, there were high levels of release point fluctuation just before the paper broke at the open draw. We could not reach the 6% draw tension because the web kept breaking at the open draw. So the limit for that type of web was 5.5% (starting to show web instability). Therefore we presume that each type of paper has a limit not to exceed in draw tension after which variability of the release point starts increasing significantly, thus creating higher risk for web breaks.

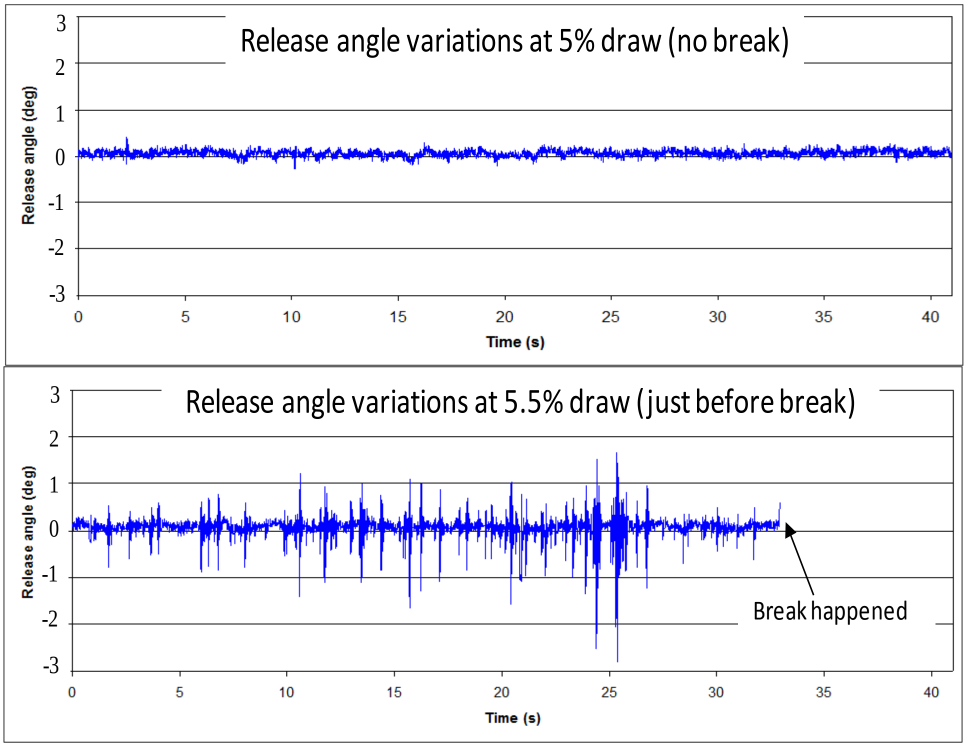


Figure 6 – Release angle variations at 5% and 5.5% draw tension at the open draw, just before a break occurs

Case Study 2:

In this case study, there were several web breaks at the wet-end section of a fine paper machine. The mill suspected breaks to occur at the open draw section and require our help to look at open draw stability in term of moisture, release and draw. MD measurements of these parameters at the open draw between press and dryers section are shown on Figure 7. Only a snap-shot of the measurements is shown here, as complete time profiles were recorded over several hours. The MD moisture profile was relatively stable in time, with no sudden variations that could explain web break at open draw. We see that there is probably a link between release angle and draw variations in MD, especially at lower frequencies. But as for the first case study, we did not find a link between moisture variations and release or draw variations. Indeed, moisture variations seemed to occur at a much faster rate in time than release or draw variations.

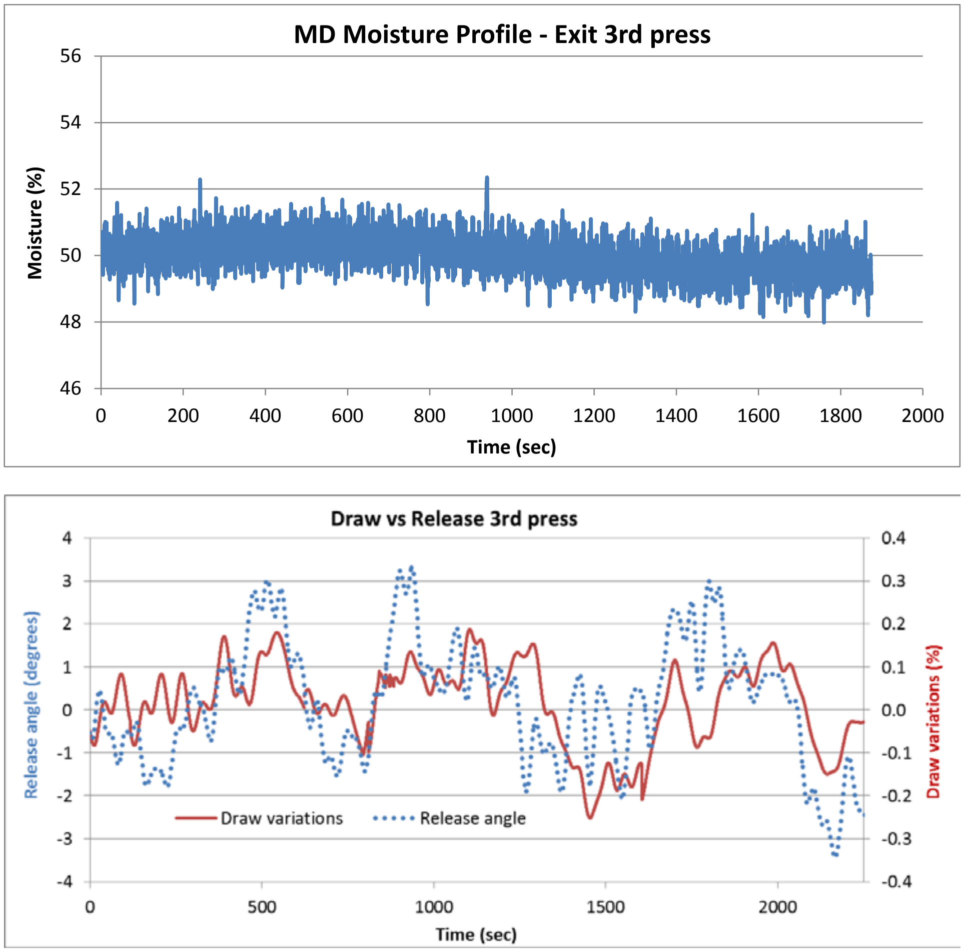


Figure 7 – Draw vs release angle in MD at the exit of 3rd press

As shown on Figure 8, there were two dominant frequencies for the MD moisture FFT spectrum profile, with no corresponding frequency in the release and draw FFT spectrum profiles. MD moisture variations were showing higher frequency cycles in time than the release angle (that show some rapid variations in time, but at a much lower rate than MD moisture) or the draw (which shows slower variations in time).

Overall, the web was rather stable in terms of moisture, release and draw. All these three parameters showed acceptable variations in their amplitude and did not explain the web break issues at the wet-end section of the paper machine. However, there was no reported web break during the different measured periods, so the question here is what would profiles look like in a problematic period? To explore furthermore the variations with the mill during problematic periods where web breaks occur, major modifications to the actual setup would be needed as this would require a long-period setup. The setup we used was OK for few hours measurements and was not suitable for longer period of continuous measurements (such as over a few days). According to the mill, moisture profiles at the end of the paper machine (reel scanner) are usually stable and uniform during web breaks period, but this does not mean that moisture profiles are stable at the open draw of the wet-end section. Both MD and CD variations could lead to some runnability issues and this would need to be furthermore investigated.

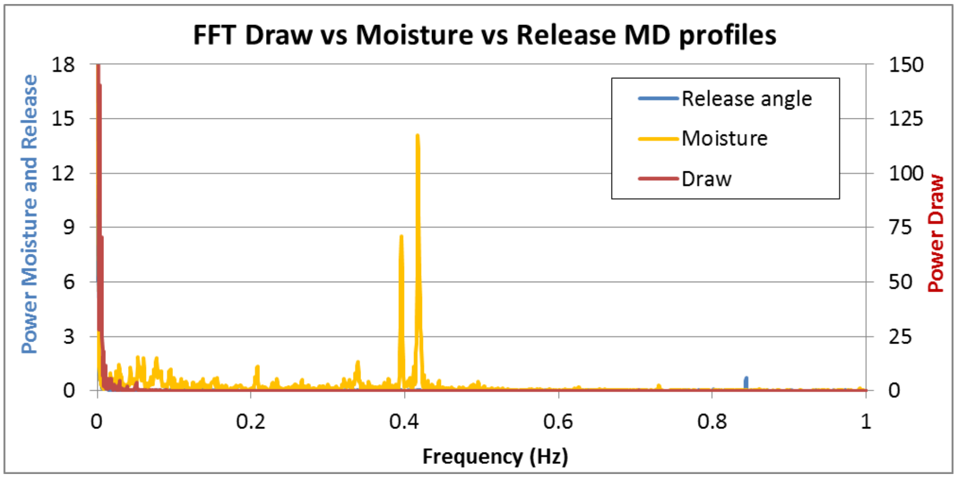


Figure 8 – FFT profiles of MD moisture, release angle and draw variations

Case Study 3:

A fine paper mill experienced episodes of high break rates at the first press open draw, with over 20 breaks per day. The mill made several changes to the wet-end section and also undertook to change the cover of that first press roll. Measurements of the release angle with the position sensor at the open draw were taken before and after the change. Measurements of the draw and moisture in machine direction, also at the open draw, were taken simultaneously. Figure 9 shows the time graphs of both the release angle and moisture, before and after the change. After the change of the first press cover, the variability (sigma) of the release angle has decreased significantly, while variability for moisture also decreased, although not as much. We were not able to find a correlation between variations of the release angle and variations of MD moisture. There was no change in the draw before and after press roll cover change, indicating that the draw was not affected by the cover change.

On the same paper machine, another change that took place was a modification brought on the drive of the flywheel located at an open draw just after the couch. We assessed the improvement in stability of the open draw by measuring the release angle before and after the drive change. As seen in Figure 10, the variation of the release distance showed a 55% reduction in the variance after the modification. This also helped to improve sheet stability at the wet-end. After these changes (press cover + flywheel drive), the mill observed that the web breaks resumed to their normal level (4-5 breaks per day), which allowed producing lighter grades with better runnability. This is a case where the tools presented in this paper helped confirm that a given change at the wet-end section had a positive impact on improving open draw stability and runnability.

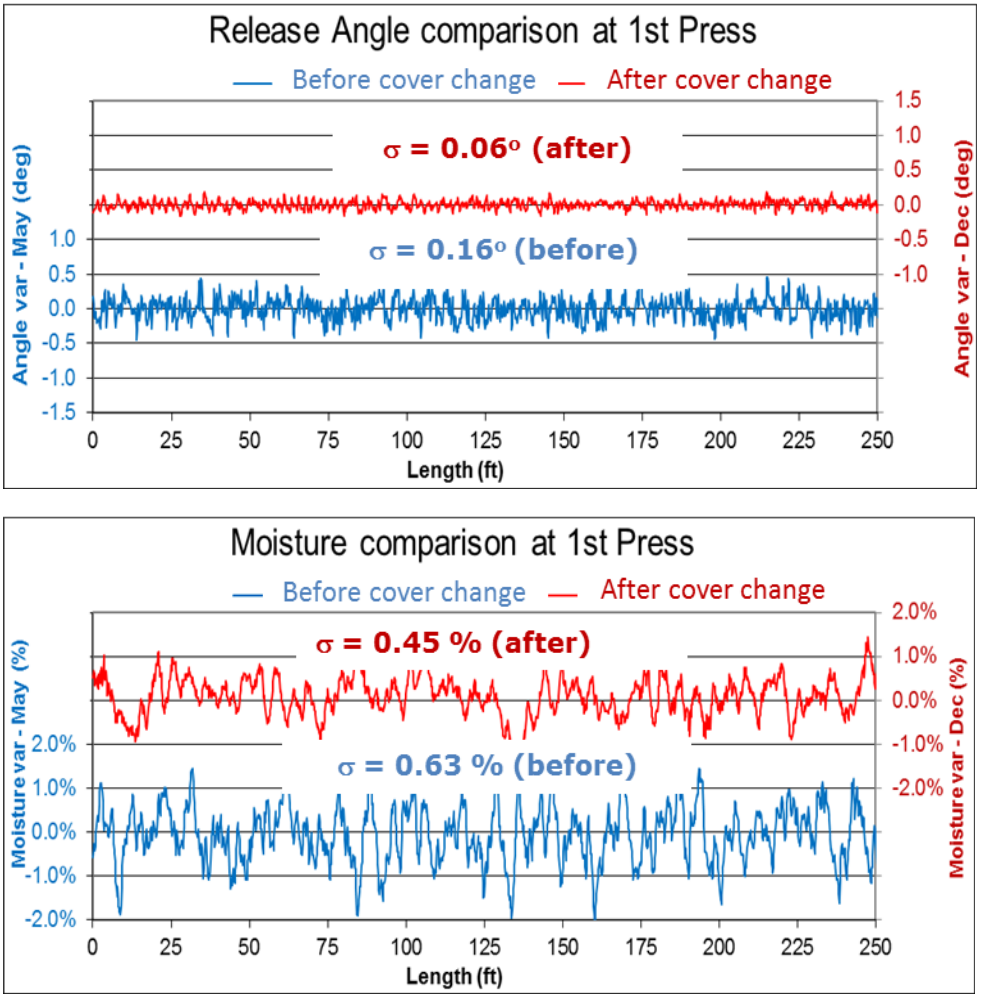


Figure 9 – Release angle and moisture time trends before and after first press cover change

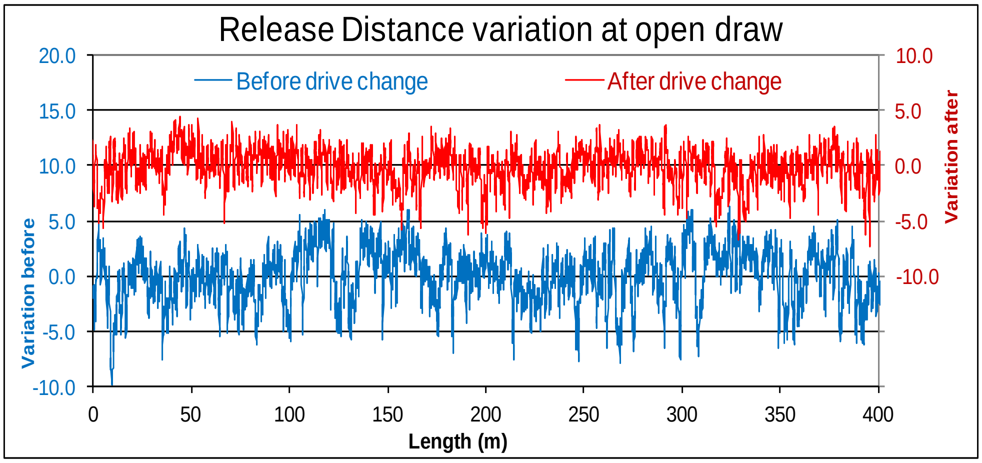


Figure 10 – Release point variation before and after drive change at the flywheel

CONCLUSION

In this study we have developed a set of tools to allow papermakers to be capable of troubleshooting paper stability at wet-end open draw, during paper production. These tools consist of a position sensor that measures web fluctuations (and release angle of the web), an infra-red sensor to measure moisture and a pair of speed sensors determining the draw variations at the open draw. These tools are all contactless and were mainly used to measure MD fluctuations. Variability of the data provides the real insight on open draw stability. If a change is brought to the machine, comparing the variability of any given measurement before and after the change may provide a good insight on how the change affects runnability.

In this paper, case studies were presented to illustrate how these tools have been used to quantify open draw stability and link this to web breaks and paper machine runnability, when possible. In all cases presented, we did not find that moisture MD variations had a significant impact on open draw instability. It was not possible to find a link between MD moisture variations and other parameters measured (release angle and draw variations). As the moisture variations in MD were rather small for all case studies presented, it is probably expected that these moisture variations would not have had a significant impact on release variations and paper machine runnability.

The parameter that seems to have the most impact on web stability at open draw is the release angle variations. For two of the cases presented, release variations had an impact on open draw stability, which in return affected the paper machine runnability (web breaks). In one case, draw variations were significant in amplitude and explained the release angle fluctuations, but in the other case there was no link between release and draw.

Finally, for one case study, all parameters measured at the open draw did not explain the cause of web break at the wet-end section. However, as all measurements have been completed during periods of time where no web break occurred, it is hard to conclude that variations in moisture, release or draw were not related to the wet-end breaks issue. As our measurements setup were not designed to monitor long-term periods (over several days), this limited the amount of information that would be needed to really conclude that open draw instability is or not related to the breaks issue.

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