EVALUATING THE IMPACT OF NON-UNIFORM PAPER PROPERTIES ON WEB LATERAL INSTABILITY ON PRINTING PRESSES

By

Frédéric Parent and Jean Hamel
FPInnovations
CANADA

ABSTRACT

Lateral instability of the paper web during printing may lead to several quality issues such as print misregistration, wrinkles, tracking issues, etc. The problem often leads to paper rejects and claims from printers. There is limited information available to paper producers on paper wandering during printing. The problems may come from the equipment, lateral control or could be even the paper web itself. An empirical study was completed with numerous paper producers to evaluate the impact of non-uniform paper properties, both cross and machine direction, on web lateral instability on printing presses. The key component of the study was to quantify web instability. To do so, portable positioning edge sensors were used during printing runs, as well as on lab equipment, to quantify the amplitude and frequency of any lateral movement. Concurrently, apparatus such as Tapio™ and one-of-a-kind paper roll testing equipment were used to measure paper properties and assess their variability. Lateral displacement and paper non-uniformity and variability were then correlated. In many cases, lateral instability of the paper on printing equipment was related to the non-uniformity of the cross-direction tension profile of the paper. Other contributors to lateral instability were the periodic variability of basis weight and fiber orientation in the machine direction. In this article, case studies of mills that have worked on reducing properties non-uniformity will be presented as well as the impact it had on web lateral stability.

NOMENCLATURE

cm	centimeter (length)
m	meter (length)
in	inch (length)
μm	micrometers (length)
g/m^2	gram per square meter (basis weight)
ft/min	feet per minute (speed)
kN/m	kilo Newton per meter (tension)

BW	basis weight
CD	cross-direction
MD	machine-direction
TSI	tensile stiffness index
TSO	tensile stiffness orientation

INTRODUCTION

Web lateral stability is critical on printing equipment to ensure good runnability and good print quality. Lateral instability such as web weaving or web shifting may lead to performance issues such as wrinkle formation, misregistration, web breaks and folder issues [1,2,3,4]. Some printing presses have capabilities to control the web lateral position. But lateral web movements are sometimes quick or so severe that press adjustments cannot compensate for them. [1,3].

Troubleshooting web lateral stability is not an easy task. The problem could come from the printing equipment itself [2,4], from the roll build [5,6], from the paper web [2,4.5], or a combination of some of these three factors.

Printing equipment such as rollers and blankets are generally aligned to prevent web lateral instability, although non-uniformity brought by the subsequent rewetting and drying processes can deteriorate it. The tension control of the press is another potential cause for web weaving, if the drive tune-up is not correct [5].

Non-uniformity paper properties in CD and MD can also generate web lateral instability [5,7,8,9]. CD non-uniform profiles induce a tendency to lateral displacement of the web. MD variations can further amplify lateral instability and lead to web oscillations in the cross-direction (Figure 1).

When web lateral instability on printing equipment comes from non-uniformity of paper properties, it is difficult to correlate the two. The lack of appropriate tools for measurements and quantification is often seen as a barrier by printers and papermakers. The printers reject the paper while the papermakers must deal with their claims. To help them understand how web lateral instability can be caused by non-uniform paper properties, we have completed an empirical study with several paper producers confronted with web stability claims from printers. The objective of the study was to determine the main paper properties affecting web lateral stability during the printing process, and work with the paper producers to correct the non-uniformity.

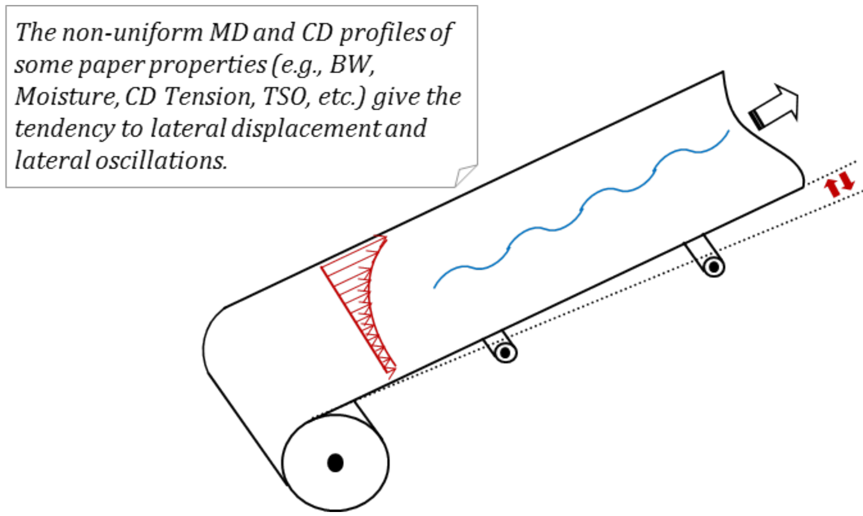

Figure 1 – CD and MD non-uniformity leading to web lateral instability on printing press

METHODOLOGY

All participating paper mills sent several paper rolls to various pressrooms to evaluate the tendency of the paper to move laterally on the press. The papermakers selected pressrooms where their rolls did not perform well on presses, with problems such as amplified web lateral movement, wrinkles or misregistration issues. Second sets of rolls from the same productions were sent to FPInnovations's laboratories for quantification of CD and MD paper properties with lab equipment. The data from both sets of trials were then correlated.

<u>Pressrooms Trials – Measuring Web Lateral Movement</u>

FPInnovations' staff went to each of the selected pressrooms to measure lateral movement of the paper. Press trials were conducted at different newsprint and commercial pressrooms in North America. Paper grades included top-coated linerboard, newsprint, super-calendered and light-weight coated paper. Several rolls from four different paper mills were measured on different presses. Table 1 describes presses specifications and problems observed on the press.

The measurements were conducted with an in-house device built specifically for this purpose. The device consists in two portable laser beam sensors installed at each edges of the web (see Figure 2) to measure web lateral movement before print and after print. The web weaving is calculated as the lateral movements of the median line, or the difference between the front and the back sensors divided by two. Calculating at the median line eliminates the impact of variations in the web width (web shrinkage for example).

Case study #	Paper grade	Type of press	Problems observed on the press	Press speed (ft/min)	Roll width (in)	Roll diameter
1	Newsprint	Goss Newsprint offset 4 colors	Wrinkles, misregistration and web breaks	1970	50	50
2	Top-coated linerboard	Goss Commercial heatset-offset 8 colors	Misregistration after print due to web weaving	1150	50	45
3	Super-calender (SCB)	ManRoland Commercial heatset-offset 4 colors	Web shifting on one side of press after drying	2650	45	50
4	Light-weight coated (LWC)	No test on press, only lab tests	Excessive web movement on press	N/A	34	42

Table 1 – Specifications of paper rolls and presses tested

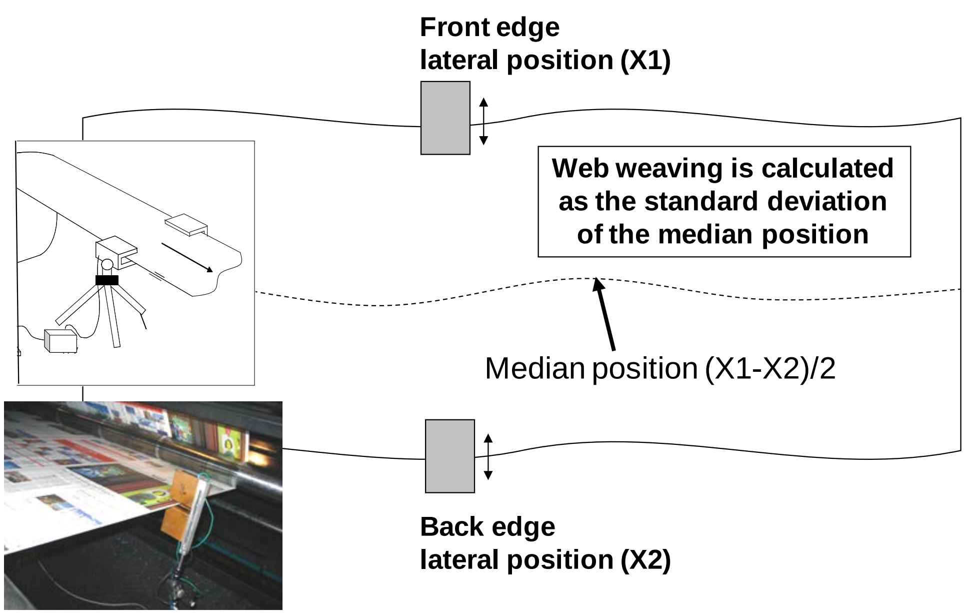

Figure 2 – Web lateral displacement measurements with laser sensors on a printing press

The web weaving was measured before print (just after press infeed) and after printing/drying (just before the slitter/folder). Only the measurements at constant press speeds were analyzed. The pasting and press stops/slow-downs were excluded from the calculation. The web weaving for an entire paper roll was calculated as the standard deviation of the median position of the web. For example, Figure 3 compares a low lateral displacement (in blue) to a higher lateral displacement (in yellow).

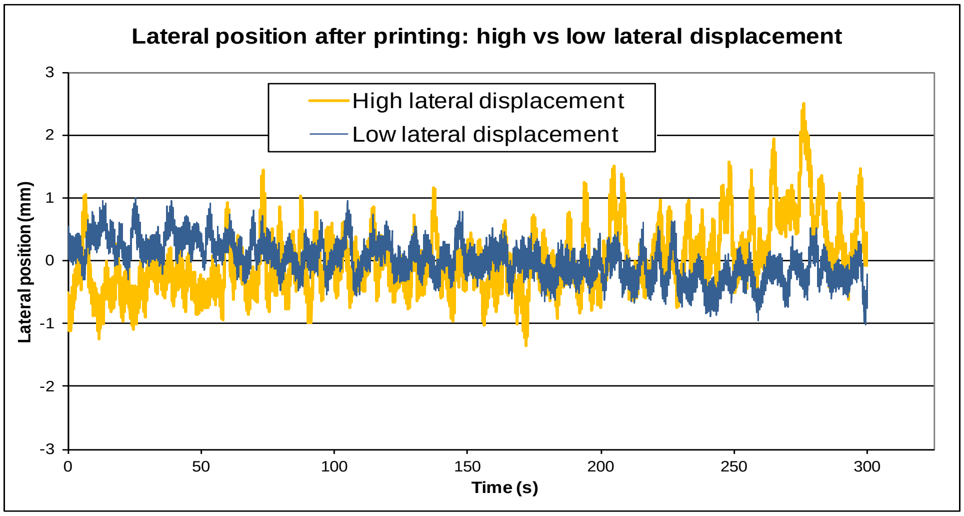

Figure 3 – Lateral displacement examples (low in blue vs. high in yellow)

Laboratory Trials – Measuring Paper Properties and Variations

For the paper properties evaluation, three laboratory equipment installed at FPInnovations main office in Pointe-Claire (QC, Canada) were used to quantify paper properties. The Roll Testing Facility was used to quantify CD tension variations, CD properties, as well as web weaving of paper rolls. The Tapio^{TM} was used to measure at high resolution, CD and MD, basis weight and caliper. The Lorentzen & Wettre TSI-TSO instrument was used to measure fiber orientation. Based on the literature [1,3,4,5,8,9,10] and on our experience with paper webs on printing presses, it was believed that these properties would be the leading contributors to web lateral instability.

All rolls were first processed through the Roll Testing Facility (RTF), equipment designed for testing rolls structure and web uniformity (Figure 4). Parameters measured included web weaving and CD tension of the web. CD Tension of the web is a quantification of the bagginess or looseness of the sheet, in CD, a property that can be measured with the RTF. The tension profile is measured at high resolution and high accuracy with a 50 in wide tension beam equipped with load cells. This tension beam was presented at the previous IWEB conference in 2011 [9]. The web lateral instability is quantified using two pairs of laser beam sensors (same as those used on printing presses) at the roll's unwind and rewind. The web weaving of an entire paper roll is calculated as the standard deviation of the median position of the web (see Figure 2). A Honeywell-Measurex scanner is used to measure basis weight, moisture and thickness of the paper web, as the roll unwinds.

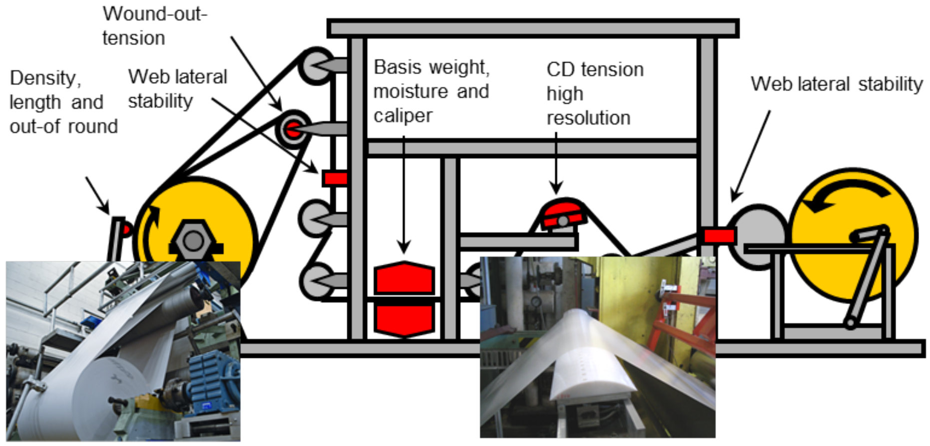

Figure 4 – Schematic representation of the different measurement completed on all rolls processed on the roll tester equipment

In order to get a much higher resolution for the basis weight and thickness properties, additional analyses were conducted with the Tapio^{TM} Paper Machine Analyzer (Figure 5). The Tapio^{TM} unit measurement resolution is 0.8mm in CD and 12.8mm in MD, enabling detection of variations within a wide spectrum, from the long (0.003 Hz) to the very short variations (40 000 Hz). Wavelengths and frequencies can then be correlated to machine component dimensions or time loops, thus allowing identification of specific machine elements causing these periodic variations.

The following parameters were measured on the T apio^{TM} unit: grammage (range tested from 45 g/m^2 to 175 g/m^2), ash content, paper thickness (range tested from 60 to 200 μm), paper gloss of top and bottom sides and paper opacity. For the purpose of this study, BW and caliper were the main properties of interest.

To measure fiber orientation, we used a Lorentzen & Wettre TSI-TSO instrument (Figure 5). This equipment was used with a resolution of 0.5 meter in the MD and 0.1 meter in the CD.

Figure 5 – Tapio^{TM} (left) and TSI-TSO (right) instruments

RESULTS

In this section, four case studies are presented to illustrate how the non-uniformity of the paper properties and their variations caused web lateral instability on printing presses. For some cases, web lateral instability was severe and led to common issues such as misregistration, wrinkles and web breaks. Note that not all measurements on web stability and web uniformity are presented and discussed. Only the measurements for which we found a relation between lateral instability and paper properties are discussed here. In some cases, solutions were proposed and applied to reduce web lateral instability, and the results after the corrections are also presented when available.

Case Study 1: Web Lateral Instability on Press Due to Non-uniform CD Tension Profile

One mill producing newsprint paper had issues with loss of register with paper rolls produced at the back side of one of their newsprint machines. Many customers rejected paper rolls from that position and requested only rolls from other positions. Figure 6 shows the web stability of the front and back rolls on the newsprint press after printing. The back roll shows higher web lateral instability than the front roll. Most back rolls displayed print misregistration. As the lateral instability was mostly random, it was not possible for the lateral control of the press to react to these sudden web lateral changes. There was also formation of wrinkles after printing.

The issue with the back position rolls visually appeared to be a lack of tension on one of their sides. Figure 7 shows the unwinding of a back position roll. The lack of tension at one of the edge is clearly visible. In this case, the baggy edge of the roll corresponded to the paper machine's back edge. Both the TSO and TSI profiles and basic sheet properties, (moisture, basis weight and thickness) did not explain this drop in tension. The mill's attempts to correct the tension at the back edge of their paper machine, by optimizing the fiber alignment, were not successful.

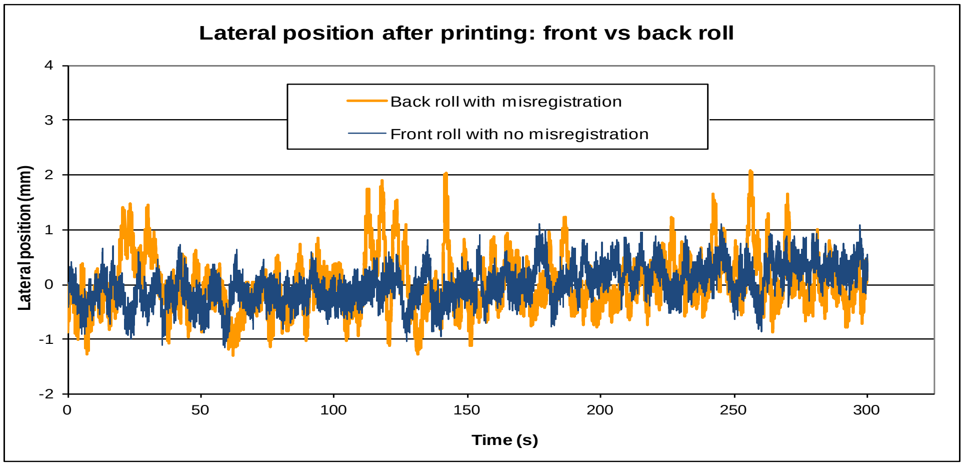

Figure 6 – Web stability on press, comparison of bad (yellow) vs good (blue) register

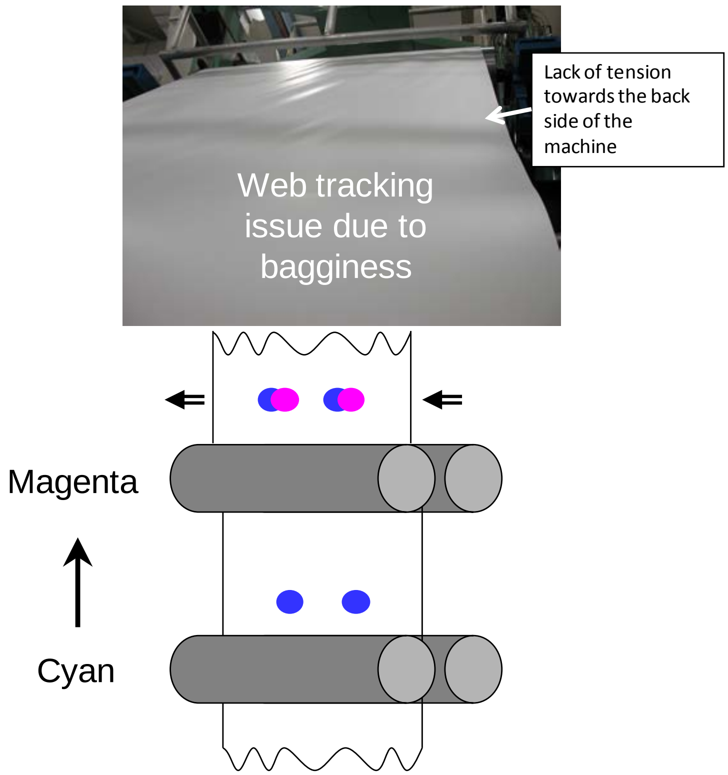

Figure 7 – Baggy edge at the back of the machine is clearly shown here at the unwind station of the roll tester. A link with web stability and misregistration is also shown.

The bagginess was quantified on the Roll Testing Facility (RTF) through the measurements of the CD tension. There was a tension difference of 0.20 kN/m between the two sides of the rolls, as shown with the curve before change in Figure 8. Typically, such a bagginess profile would come from a non-uniform moisture profile. Further analyses at the mill showed that indeed, after the press section, CD moisture profile was non-uniform. However, after the drying section, the CD moisture profile was uniform. This indicated that something in the dryer section caused the web to elongate more at the back edge of the paper machine to produce this baggy profile.

Based on previous research on the influence of moisture and modulus of elasticity on tension as well as on some research in the literature [10], it was proposed that a moisture bias at the back edge of the machine would solve the problem. When comparing moisture and CD tension, they showed a clear inverse correlation. From this finding, the moisture bias to be applied could then be calculated. By lowering the moisture at the back edge of the paper machine, the CD tension would likely increase, to produce a uniform profile and thus eliminate the baggy edge. It was determined that the moisture correction should be applied to the last 127 cm of the machine width where the bagginess zone was located. Through the control of the steambox installed at the press section of the paper machine, the mill was able to apply the moisture bias; a reduction of up to 2% over the last 127 cm. Figure 8 shows the tension profiles before and after a moisture bias application. The moisture bias clearly improved the tension uniformity. With the moisture bias, the tension difference was significantly reduced to a slope close to zero.

This improved web tracking on presses and eliminated the misregistration problems for the back edge rolls.

Figure 8 – Correction of tension profile with the application of moisture bias

Figure 9 compares different position rolls with back positions rolls before and after changes on the paper machine. It also compares the rolls with one competitor roll that was known to run well on printing press. The back position roll shows higher lateral instability before and after printing, when compared to all other rolls. The corrections made on the machine reduced the lateral instability to a level comparable to other positions and even at a level similar to the competitor roll.

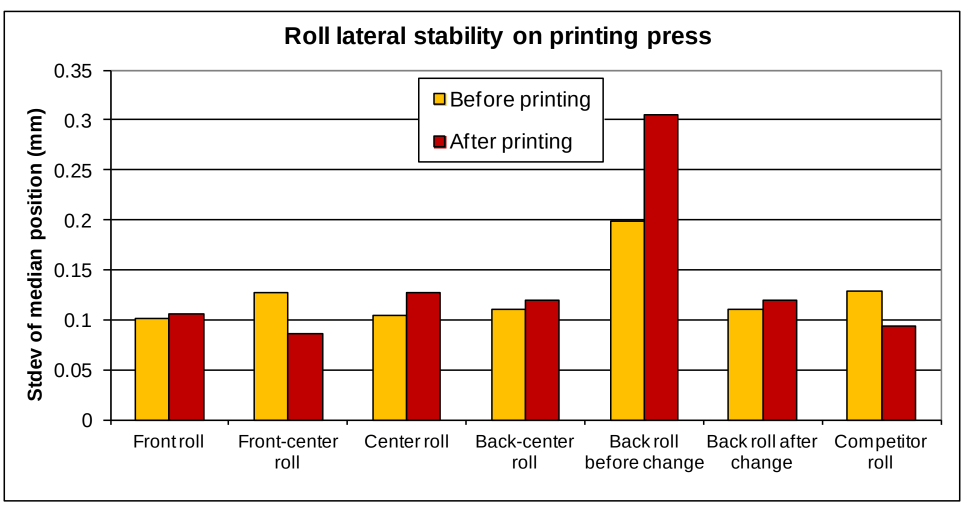

Figure 9 – Web stability on press, comparison of problematic roll with good running rolls

Case Study 2: Web Lateral Instability after Printing Due to TSO Variations in MD

One mill producing top-coated linerboard was having web lateral instability on the printing press that led to misregistration after printing. Web stability measurements showed a periodic lateral instability, occurring every 16 meters or so in MD. Web stability measurements also showed a clear correlation to web weaving and print misregistration (Figure 10). This suggested that the web periodic lateral movement was likely causing the print misregistration.

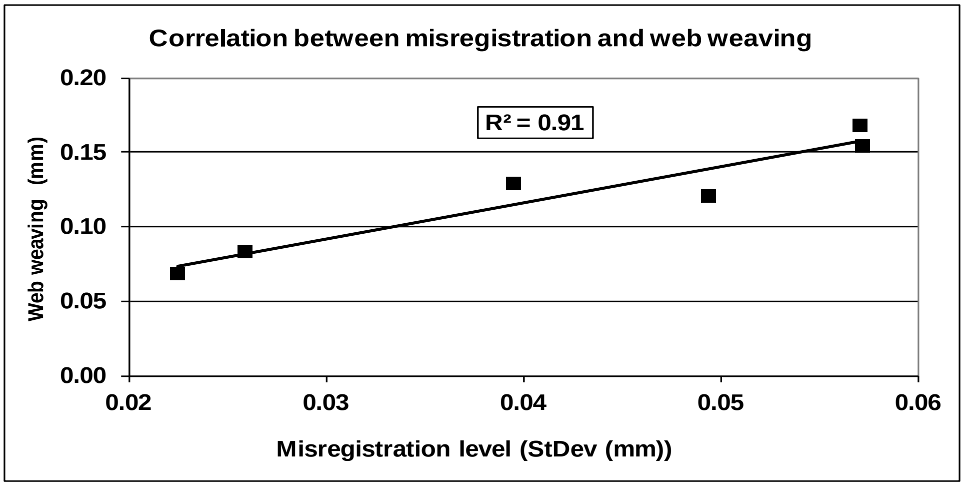

Figure 10 – Correlation between print misregister and web weaving

With such a short wavelength (16 meters), it was not possible for press operators to control or reduce the weaving. Even S-wrap was added to improve web stability; however it slightly improved the stability on the press at higher periods (above 50 meters) but not at the period observed with the paper and therefore did not improve the registration issue. The roll's structure analysis had not shown any evidence of web weaving sources. We then suspected MD web property variations. Lab measurements of the web properties were conducted, to evaluate for variations in MD. As shown in Figure 11 a periodic variation with a wavelength of 16 meters was detected in the fiber orientation. This corresponded to the same wavelength measured in the web weaving on the press. It was concluded that the fiber orientation varied from side to side of the roll, possibly modified the web tracking on press and lead to web movement every 16 meters.

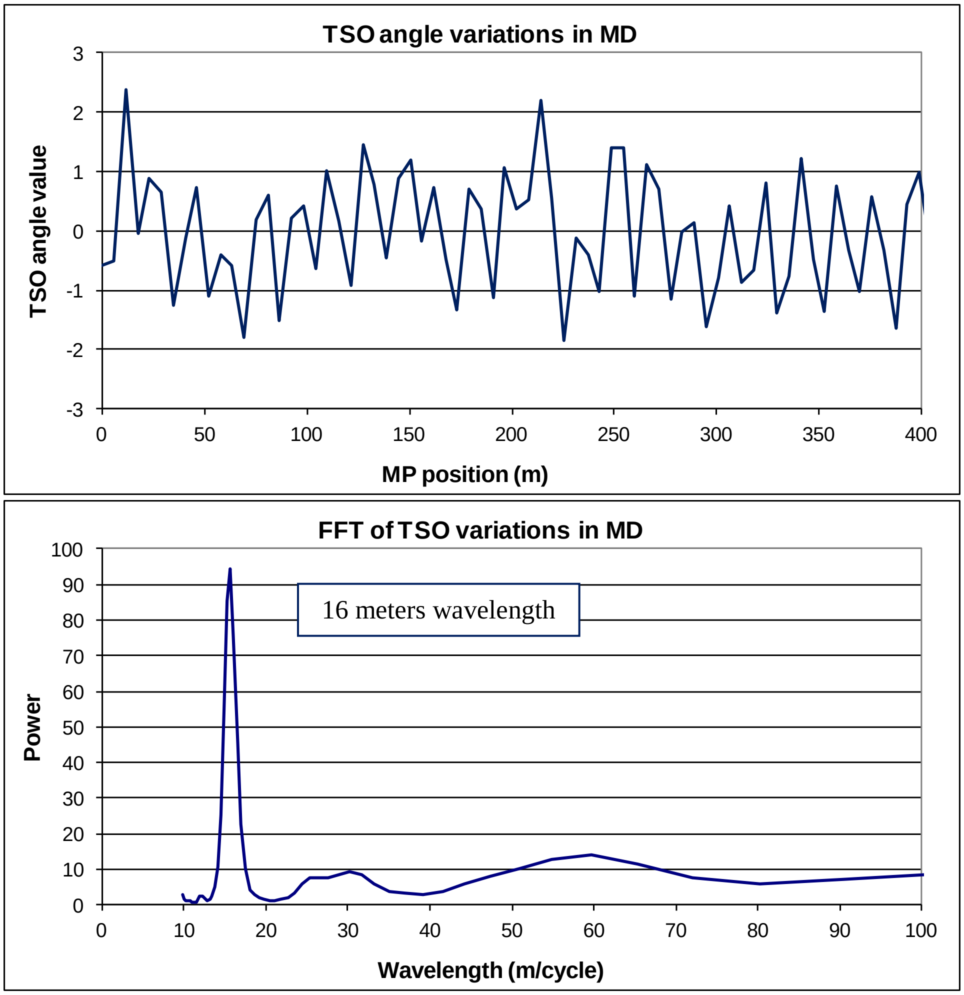

Figure 11 – Periodic variations found in TSO MD leading to web weaving on press.

TSO angle variations in MD were the main source for web weaving. In the end, we found that they were caused by headbox pulsations, as shown on Figure 12. Headbox pressure was recorded at the mill using the DCS system. The headbox pulsations were periodic and were generated by the fan pump. After the fan pump was replaced, the main frequency in the headbox pulsations disappeared, as shown on Figure 12. The fan pump replacement also allowed significant reduction of the TSO variations in MD. This improved the web weaving on the printing press to an acceptable level. No measurement was completed on the press after the fan pump replacement since the problem had gone away.

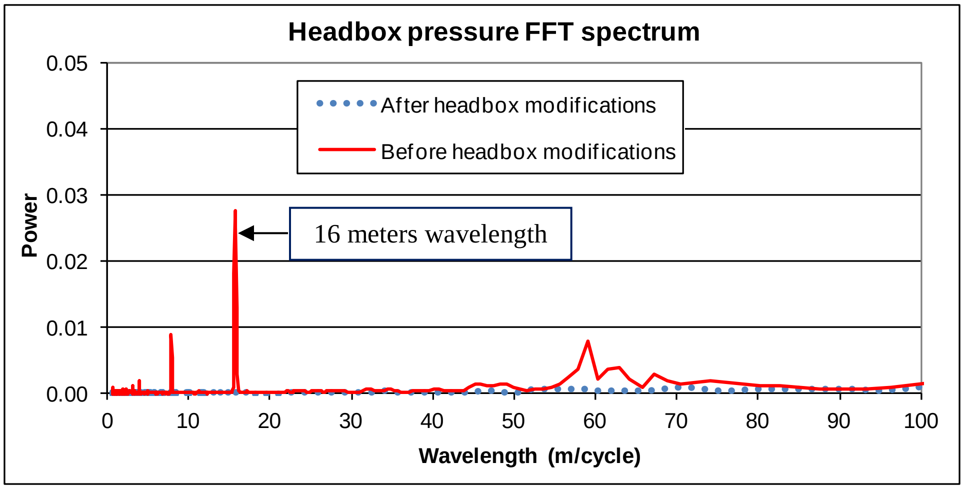

Figure 12 – Periodic variations found in TSO MD and headbox pressure before and after correction to the fan pump on the paper machine

Case Study 3: Web Shifting after Drying Due to a Non-uniform CD Tension Profile

One paper mill producing super-calendered paper (SCB grade) had a web shifting issue at one pressroom. The web shifting mainly occurred after the dryer section on the commercial printing press. The problem only occurred with edge rolls (front and back positions of the paper machine). The front rolls were shifting towards one side of the press and the back rolls were shifting towards the opposite side of the press, as shown on Figure 13. The web shifting was so severe (up to 25 mm towards the sides of the press) that the lateral control of the press could not compensate for it. The shifting therefore caused issues at the cutter and at the folder, such as wrinkles.

The paper mill had noticed that their TSO profile in CD was not adequate and suspected it could be responsible for the web shifting. But TSO improvement did not solve the web shifting issue on press. Further analyses allowed determining that the web shifting was related to non-uniform CD tension profiles. Indeed, the CD tension profiles of both the front and back edge rolls were not uniform. They showed what is commonly called ‘baggy edges’: a strong tension drop towards the paper machine edges. The tension difference between the two sides of each edge roll was more than 0.20 kN/m.

This highly asymmetric profile in CD tension was likely the cause of the web shifting observed in the pressroom. Similar to the first case study, this web tension non-uniformity caused the web to track towards one side of the press, also causing wrinkles. The edge rolls showing opposite profiles, this explained the front rolls shifting towards one side, and the back rolls shifting towards the other side of the press. The reason why the web only shifted after the dryer (and not in previous sections of the press) is likely because of the lack of web support in the dryer. The sheet was free to move sideways.

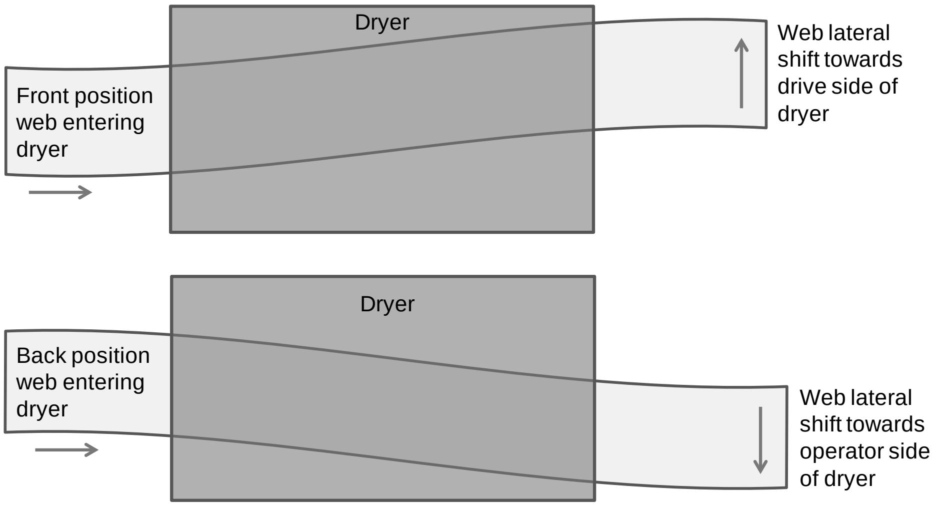

Figure 13 – Schematic representation of web shifting after the dryer on commercial high-speed printing press, towards opposite sides depending on the position of the rolls

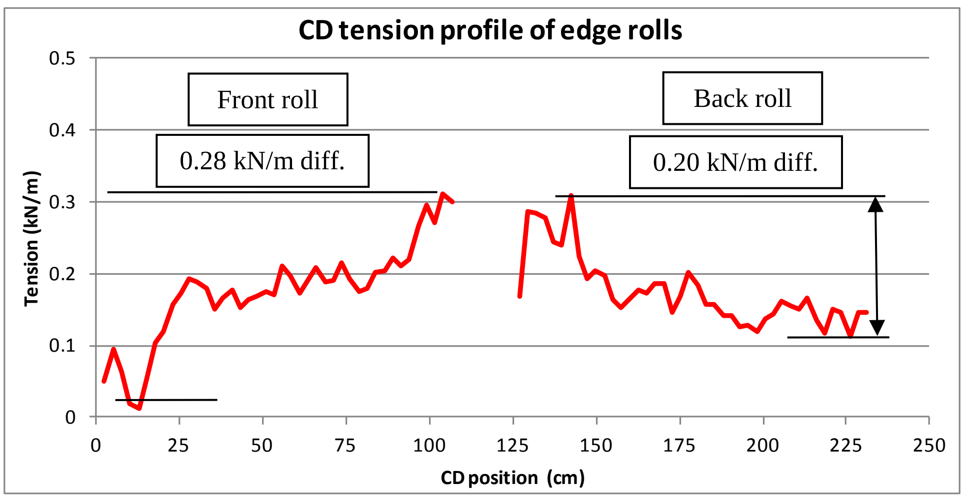

Figure 14 – Non-uniform CD tension profiles at the paper machines edges

Properties measurements also allowed identifying the cause of the non-uniform CD tension profiles of the edge rolls: non-uniform moisture profiles in CD. There was a significant inverse correlation ($R^2 = 0.73$) between tension and moisture. High moisture content corresponds to lower tension, and vice-versa (Figure 15). A moisture increase of 0.5% caused a tension decrease of over 0.15 kN/m. Ultimately, the decrease in tension towards the edges of the machine was explained by the non-uniform moisture profiles at the edges.

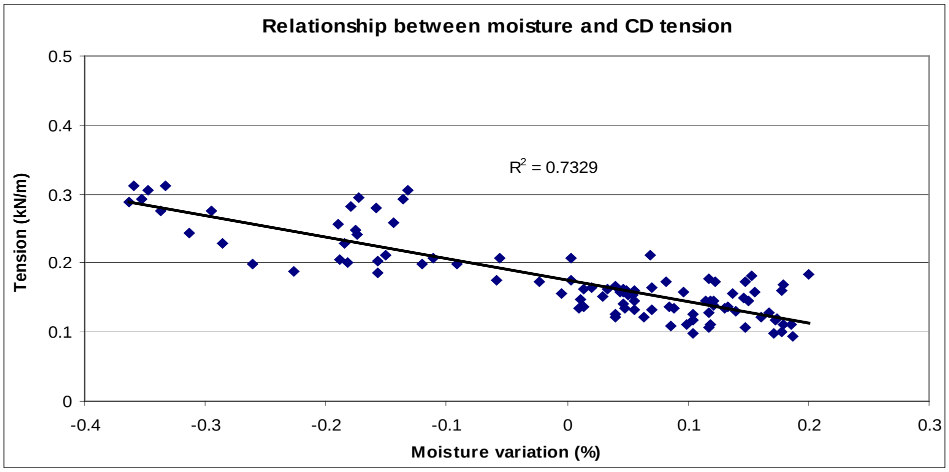

Figure 15 – Relationship between CD tension and CD moisture profiles at the reel

The mill found that the non-uniform moisture profile was coming from the press section. One press roll cover was worn and did not efficiently remove water at the edges of the paper machine. A press roll change allowed making the moisture profiles more uniform after the press section. This had a significant impact on the CD tension profiles, and allowed eliminating the baggy edges (Figure 16). Uniform CD tension profiles allowed a reduction in web tracking issues on press and improved the web shifting.

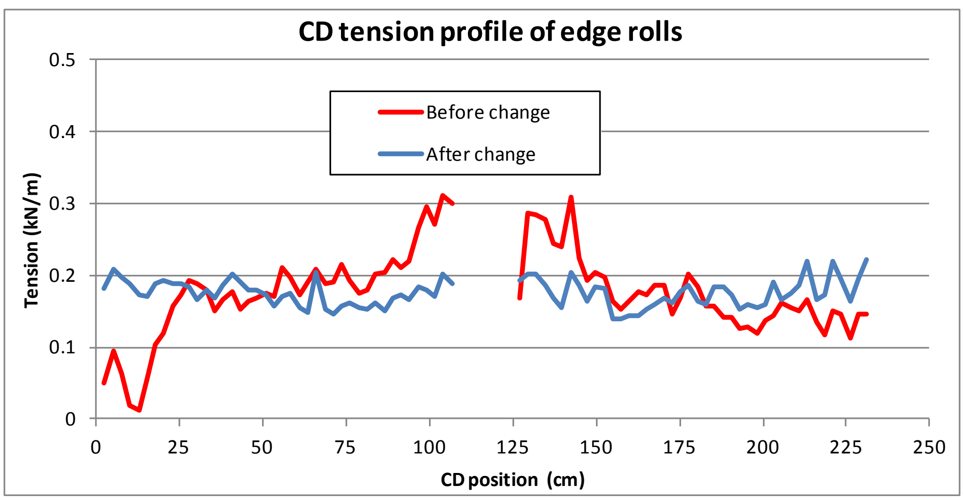

Figure 16 – Uniform CD tension profiles at the paper machines edges after moisture corrections on the paper machine

Case Study 4: Excessive Web Weaving on Press Due to MD Properties Variability

One paper mill experienced severe web weaving issues in one pressroom. The web weaving was mainly problematic at the press folder, where lateral movements reached up to 10 mm. Folder adjustments could not compensate for this high lateral variation. Web lateral movements were also observed at the printing units, where they caused misregister. Figure 17 shows the lateral oscillations measured on the roll tester equipment for one field rejected paper roll and for one good running paper roll from competitor. The web weaving of the rejected roll has a periodic pattern with frequency variation of wavelength 13.7 m in MD. The competitor's roll did not show any variation in the web weaving, which was very low.

Analysis of the CD properties showed adequate and non-problematic profiles. Winding was also suspected as a potential cause, but the roll structure parameters were appropriate, showing a good wound-out-tension curve, and low out-of-roundness. Only the MD properties analysis allowed identifying a variation of wavelength 13.4 m in both basis weight (Figure 19) and ash for the rejected roll. This was the same wavelength as the one identified in the web weaving. The amplitude of this variation was high in both basis weight and ash. It was likely originating from a non-uniform coating application, since the base sheet hardly had any ash in it. The competitor's roll did not show any variation in the basis weight of ash MD profiles (Figure 19).

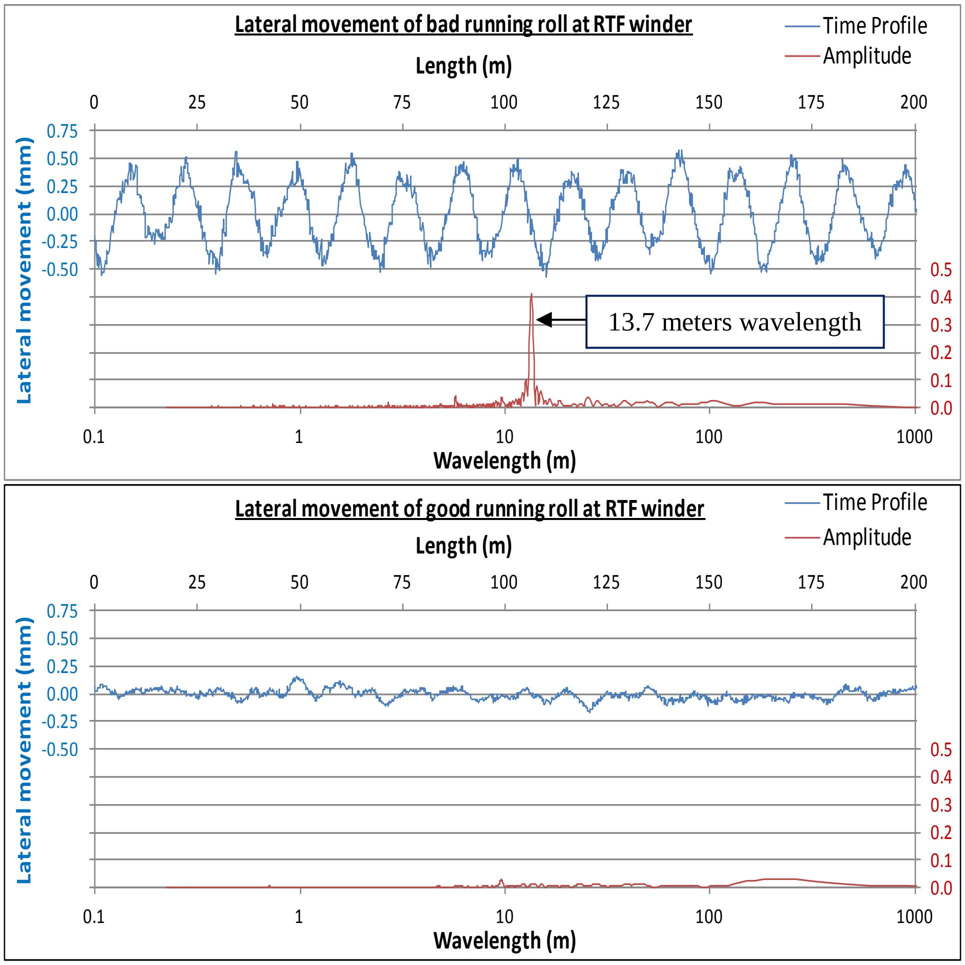

Figure 18 – Lateral movement measured at the RTF winder (bad vs good running roll)

Following these findings, the mill strongly suspected the coating operation as the potential cause for web weaving. Wavelength found in the basis weight and ash variations corresponded to one turn of the coater rod. After changing the coater rod, more rolls were tested on the printing press. This corrective action of changing the coater rod was successful in reducing web weaving variations to the level of the competitor rolls.

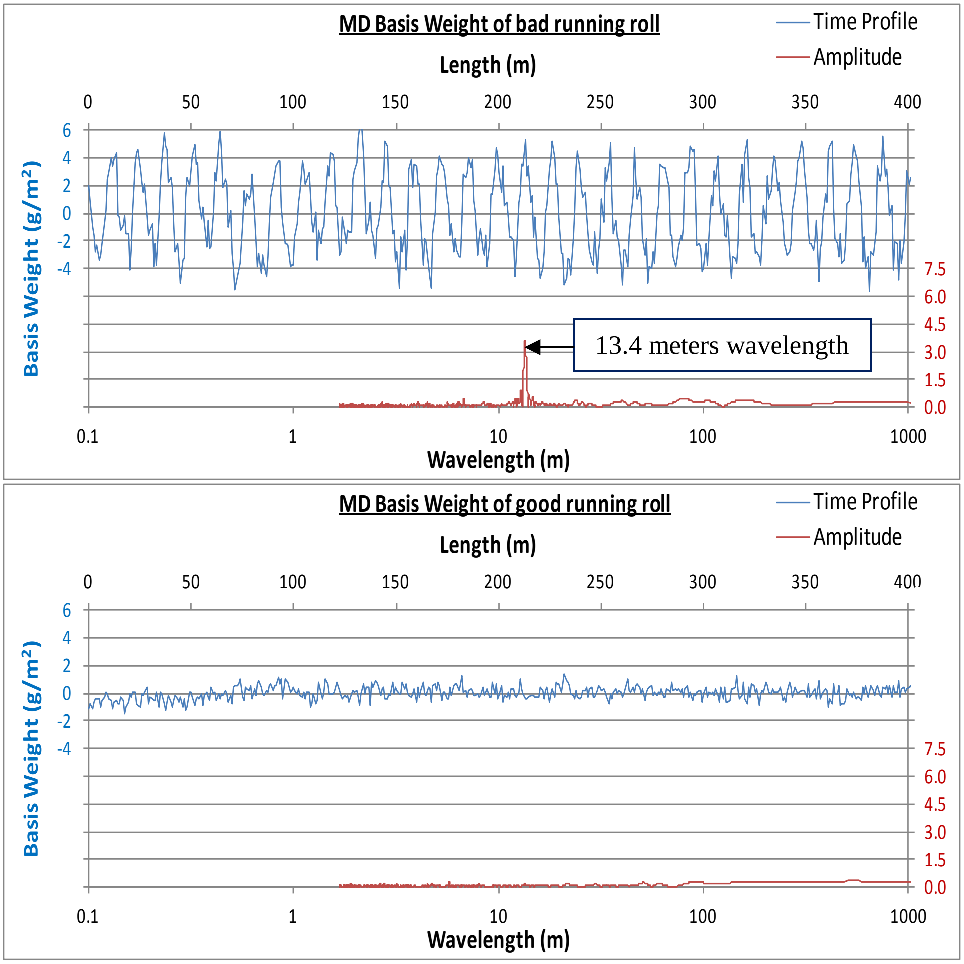

Figure 19 – Basis weight variations in MD measured for good and bad running rolls

CONCLUSION

In this empirical study, we have attempted to find the impact of paper properties non-uniformity on web lateral instability on printing presses. Several measurements using portable positioning edge sensors were completed to quantify web instability on press. Sophisticated apparatus were used to relate the lateral instability measured on press to the paper properties non-uniformity. In many cases, lateral instability of the paper web was related to the non-uniformity of the cross-direction tension profile of the paper. Other contributors to lateral instability were the periodic variability of basis weight and fiber orientation in machine direction. Case studies were presented to illustrate how some paper mills have worked on improving paper properties to reduce web lateral instability.

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