Papermaking Factors Affecting Lateral Web Position during Commercial Heat Set Web Offset Printing

George Shields[1], Alexandra Pekarovicova[2], Paul D. Fleming[2], Jan Pekarovic[2]

1UPM Kymmene Co.
[2]Center for Printing and Coating Research, College of Engineering and Applied Science, Western Michigan 4601 Campus Drive, A-217 Parkview, Kalamazoo, MI 49008-5462

Keywords:
heatset web offset litho printing, web shifting, fiber orientation

Abstract
In the offset lithography process, a dampening solution is necessary to form a thin, low viscosity water-based film on the non-image areas of the printing plate. The film protects the non-image areas from direct contact with the oil-based printing ink and keeps it free of ink. The main component of the dampening solution is water (80-95%), the rest comprises of surfactants, often isopropanol and other functional additives (e.g. anti-bacterial agents). Due to the high speed of the commercial printing with heat set web offset presses it cannot be avoided that before the dampening solution is evaporated completely, the remaining part of the dampening solution is transferred from the non-image areas to the blanket and then directly to the paper. Since the dampening solution is provided continuously to the printing plate, also on image areas water is transferred onto the ink carrying surfaces and the next over rolling inking rollers "emulsify" the water into the ink. The interaction of water with paper plays a role in web handling characteristics during commercial heat set web offset printing. Water absorption leads to lower web tension for a given strain. The purpose of this work was to determine the papermaking reasons for lateral shift of the moving paper web made from a particular paper machine on a specific printing press during heatset web offset (HSWO) printing. The lateral movement is seen as a steady state shift to the gear side of the printing press, which can be measured at the exit of the chill section. In upset conditions, such as start up or blanket wash the web may shift so far that it runs off the paper guiding rollers and/or jams the folder section of the printing press. The paper in question is a coated mechanical paper made on a Fourdrinier paper machine (PM) in the northern United States using pressurized groundwood (PGW) mechanical pulp and northern bleached softwood kraft (NBSK) pulp. The paper is coated with a blend of kaolin and ground calcium carbonate pigments along with starch and latex binders, and supercalendered to 64% gloss. Absorption rate testing showed that uncoated supercalendered (SC) papers (not from target paper machine) absorb water faster than the target PM, yet suffer no lateral movement during printing. The reason for lower web tension in the target paper machine web is most likely due to lower fiber orientation. Fibers oriented in the direction of stress have reinforcement from the cellulose microfibrils. The stiff microfibrils serve to reinforce the matrix and prevent movement. Fibers oriented in the cross direction do not have this reinforcement. Therefore, a less oriented sheet has less reinforcement from the microfibrils and is more susceptible to movement of the matrix.

Introduction

The effects of water and heat on the behavior of paper sheets have been studied frequently over many years. Two effects of water on paper sheets, either in liquid or vapor form, are hydro/hygro-expansion (Kajonto & Niskanen, 1998) and softening of the fiber matrix through plasticization (Niskanen, 1998). In both cases, it appears that water molecules interact with fiber material through a hydrogen bonding mechanism. Swelling of the fiber wall and translation of the swelling to the paper sheet dimensions is the result of hydro/hygro-expansion. Fiber plasticization and the corresponding loosening of the fiber matrix occur because water acts as a softener preferentially bonding with hydroxyl sites in the amorphous polysaccharides in or between the microfibrils which makeup fibers.

The lateral shift from right to left in press direction has been observed on several HSWO printing presses running the subject paper and attempts to correct the problem have met with little success. The propensity of the web to shift in the extreme during upset conditions has been linked to how the web shifts under steady state printing conditions. For the paper in question made under specific conditions, the amount of water applied during printing appears to govern the magnitude of the lateral shift during steady state conditions (Shields, 2015).

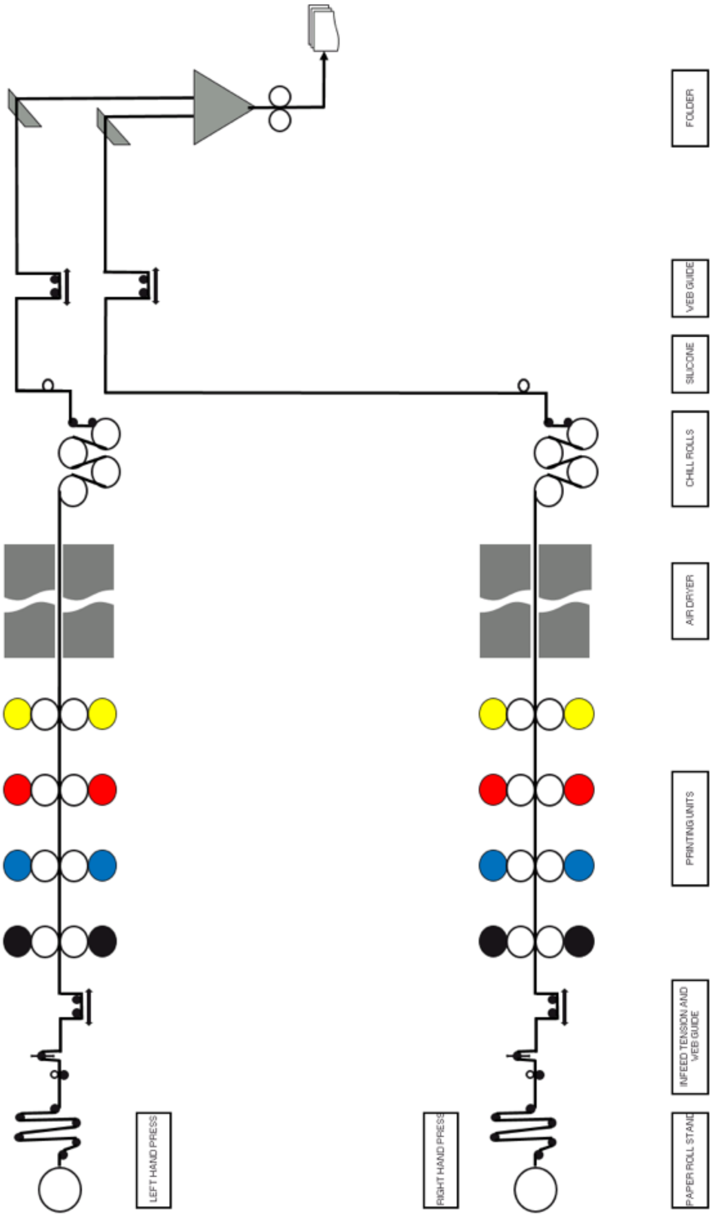

Figure 1: Schematic diagram of the target printing press side by side layout.

The subject printing press is a side by side design of two web HSWO presses operating at a nominal speed of 1600 fpm. Figure 1 illustrates the pertinent parts of the target printing press. Each web is fitted with a reel, pre-tensioning section and guiding section prior to 4 printing units and a 3-zone hot air floatation dryer followed by a chill section. One of the two webs (Left Hand Press, LHP) follows with a short web lead, displacement guide, silicone applicator, slitter section and then on to a combined folder section. The second web (Right hand press, RHP) is identical to the LHP through the chilling section but differs after in that the web passes through a silicone application unit and then a long web lead which crosses two 45° air turns before meeting a displacement web guide, slitter section and the common folder section. A key factor in the design of the target press is the extra distance the web travels between the chill section and web guide on the RHP. The distance is 17.4 m. Assuming a nominal press speed of 8.1 m/s the extra time is 2.15 s. The RHP is the subject of this work.

The hypothesis, for why the lateral web shift occurs, is related to the air currents within the floatation dryers of HSWO printing presses. The air currents have a machine direction component and a lateral component. Low web tension allows the lateral component of the air flow to move the paper web sideways. Papers with higher web tension will be less impacted by the lateral air flows and therefore be more centered on the printing press. Moisture addition from printing will reduce the tensile stiffness of the paper and therefore web tension. The time from water application to drying during printing is short and it is possible that the rate of tension loss is more important than residual steady state tension. The lateral movement of the target paper machine appeared to be related to the loss of tension between printing and chill section exit. Figure 2 shows a schematic of the area in the printing press where the lateral shift occurs. Understanding the methods to reduce the lateral web movement may lead to further understanding about the impacts of water on sheet properties during HSWO printing and possibly methods to reduce web break rates for papers made with mechanical pulps.

Papers tested

Eleven trial rolls were manufactured on the target paper machine with the following changes to standard conditions:

- Vary the fiber orientation through the use of edge flows on the headbox, and selecting rolls from different positions across the paper web,
- Increase the strain on the web at approximately 20% moisture content,
- Increase the strain on the web in the dryer section between 45 – 95% moisture content,
- Reduce fiber orientation through reduced jet/wire ratio,
- Vary SBK (Softwood Bleached Kraft pulp) fiber refining,
- Vary hardwood PGW (Pressurized groundwood) fiber refining,
- Vary the wet end starch addition rate.

In the following text, these papers are referred to as “trial papers” (Table 1). In the laboratory, papers from the 11 trial conditions plus 14 other paper samples, 11 of which are known to not suffer from lateral web movement, were tested for stress-strain behavior and moisture content at various humidity levels. The moisture contents of the papers after printing but before drying were calculated using a quantity of 3 g/m2 (gsm) moisture estimated to be added during printing (Per-Olav, 1995; Kela and von Hertzen, 2007). The absorption rates of the papers were measured using ultrasonic techniques.

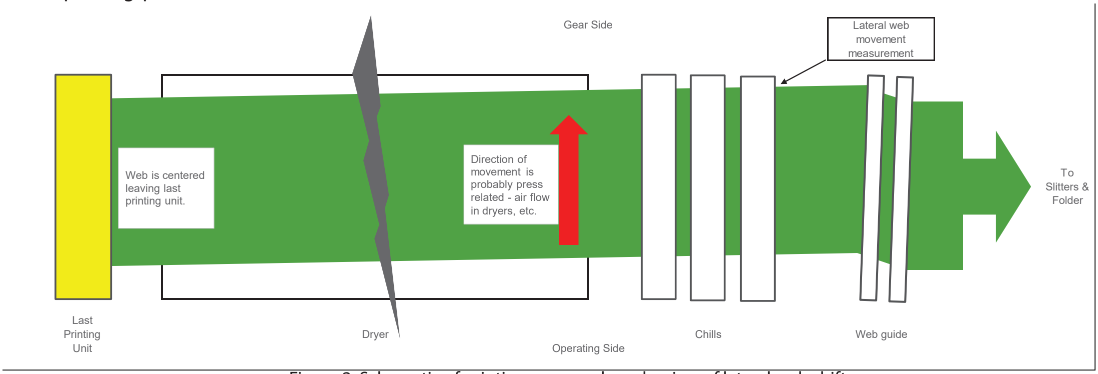

Figure 2: Schematic of printing press and mechanism of lateral web shift.

Table 1: Trial papers. J/W- Ratio of headbox jet velocity to forming fabric velocity, SBK- Softwood Bleached Kraft pulp, PGW - Pressurized Groundwood

1	Standard Front Edge Roll
2	Standard Center Roll, increased fiber orientation
3	Edge Flow Closed, increased fiber orientation
4	Increased Strain at 20% Solids
5	Reduced J/W Ratio, decreased fiber orientation
6	SBK Refining Increased
7	SBK Refining Decreased
8	Zero PGW Refining
9	Lower Wet End Starch
10	Higher Wet End Starch
11	Reduced Strain at 90% Solids

Ultrasonic Intensity
The ultrasonic absorption rates were checked for both sides of the paper samples. The device used was the Emtec EST12 Surface and Sizing Tester. Sample testing was done in accordance with unit operating instructions (Emtec Electronic GmbH, 2005). The samples were tested one side at a time and the results were reported as side A and side B for each tested paper. Analyses of the absorption rates were made according to (Gigac, Stankovska, & Kasajova, 2011), and Emtec (Emtec Electronic GmbH, 2002). The absorption curves were plotted, and two parameters derived from the measurements were reported; t95 and USI70. The shape of the ultrasound intensity curve tells about how the test fluid penetrates the paper sample. Overall absorption rate was inferred from the slope of the curve. The faster the reduction in ultrasound intensity, the faster the liquid penetration. The t95 factor calculated with an isopropyl alcohol in water test liquid gives information about the pore structure of the paper (Emtec Electronic GmbH, 2002) (Gigac, Stankovska, & Kasajova, 2011). The USI70 factor, using water as the test fluid gives information about the surface roughness of the paper samples. Samples were selected from a range of basis weights and coated/uncoated conditions.

Fiber Orientation
Tensile strengths were measured in both paper machine and cross machine direction. MD tensile strength and CD tensile strength of the samples were measured at 50% RH, 23°C (TAPPI standard conditions) and the ratio of MD/CD tensile strength was reported as Tensile Ratio. Tensile Ratio is an indicator of fiber orientation (Niskanen, Kajano, & Pakarinen, 1998, p. 37).

Results and Discussion

The print trial results for the 11 trial papers (Table 1) are shown in Figure 3, exhibiting the relative positions (in 1/32 ") of the sheet edges during steady state printing for each condition. A larger result means the web was more centered on the press corresponding to less potential for lateral web movement under blanket wash conditions.

One condition performed very well (Edge Flow Closed) running almost centered in the press during normal printing operations. One condition performed quite poorly (J/W reduced to -50 fpm) running significantly off center. One condition was marginally better than the Standard Front Edge roll, with increased Strain at 20% solids. All other conditions were about equal to the Standard Front Edge Roll.

According to the print trial results, the conditions with higher expected fiber orientation performed quite well, while the condition with the lowest expected fiber orientation performed poorly. The Increased Strain at 20% Solids condition performed marginally better than Standard. Increased strain at low solids can contribute to increased fiber orientation (Retulainen et al, 1998).

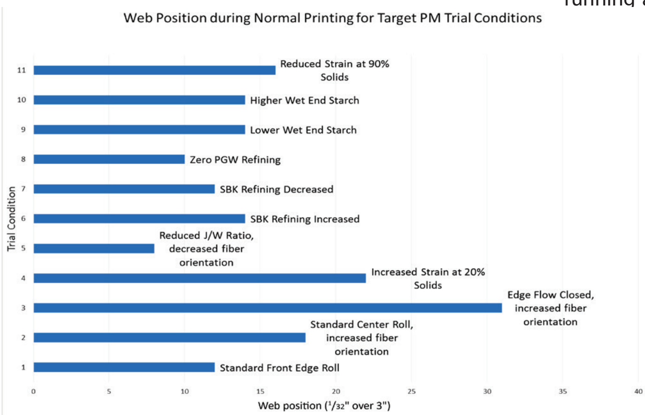

Figure 3. Print trial results for target paper machine conditions.

Overall, the best result was achieved with edge flow closed at headbox (Trial condition 3), which causes increased fiber orientation of substrate. Again, higher result means the web was more centered on the press corresponding to less potential for lateral web movement.

It is possible that the rate of absorption of water, from the fountain solution or blanket wash, differs for the various papers. A slower rate of absorption would give a higher tensile stiffness at a given time after printing (i.e.-water would not have absorbed and interacted with the fiber walls and bonds between fibers). To investigate this possibility, or to predict the rate of absorption, EMTEC ultrasound intensities were measured. The loss of tension can be attributed to water uptake. It is possible that the rate of absorption of water, from the fountain solution or blanket wash, differs for the various papers.
Ultrasonic absorption rates for a portion of the paper samples were measured using distilled water and then again using a mixture of 16% IPA in distilled water. The IPA lowers the surface tension of water and allows for faster wetting of the paper surfaces. The ultrasonic intensity curves using water as the penetrating medium are shown for selected samples. Samples were selected based on a range of basis weights (13.29-50 gsm) and coated/uncoated conditions.

Figure 4 shows results using distilled water and Figure 5 using 16% IPA in water solution. The Emtec device functions by sending a 2 MHz signal through the penetrating liquid and paper samples. A portion of the transmitted signal is reflected by the liquid/paper interface. A portion of the signal is scattered by air trapped in the paper structure or on the surface during the absorption process. And, as the liquid comes in contact with the fiber, the elastic properties of the fiber change (Emtec Electronic GmbH, 2002). The percentage of the initial ultrasonic signal reaching the receiver is known as the ultrasonic intensity. The shape of the ultrasonic absorption curves contains information about the rate that the penetrating liquid is able to sorb into the paper structure and some information about the paper surface characteris-

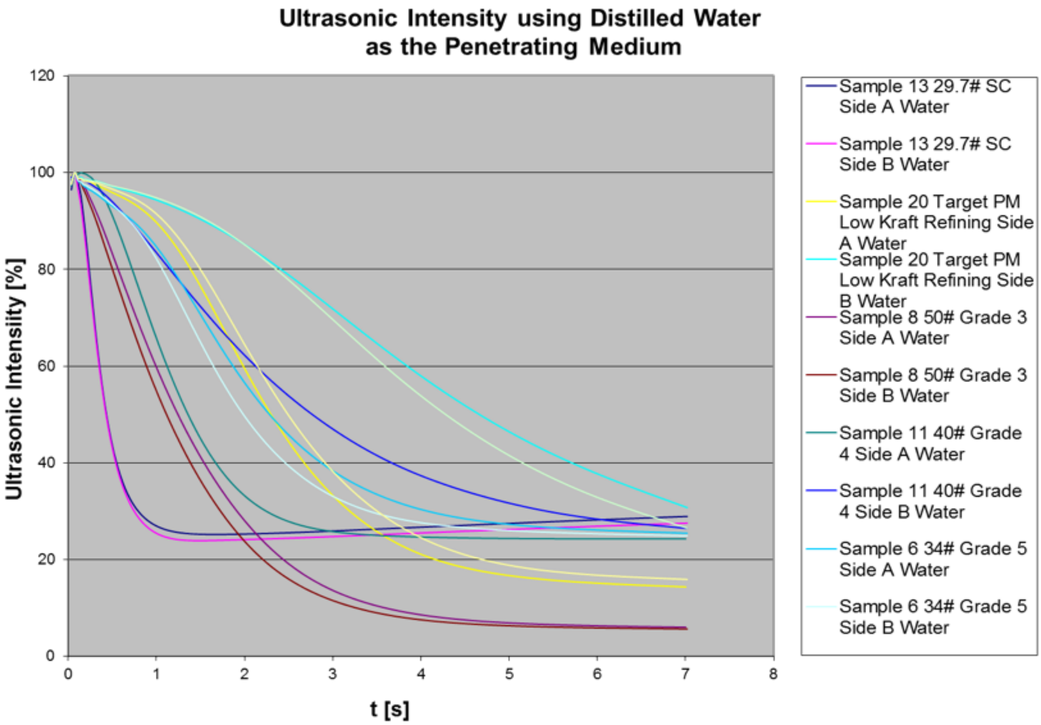

Figure 4: Absorption of water measured by ultrasonic intensity. Inset shows detail of papers behaviour within first 0.5 seconds. (50# means 50 lbs/3300ft2. That's 74 gsm.)

tics and pores. Four factors mainly influence the ultrasonic intensity measured by the device (Emtec Electronic GmbH, 2002).Increasing ultrasonic intensity passing through to the receiver, due to decreasing reflection on the liquid/paper interface.

- Decreasing ultrasonic intensity passing through to the receiver, due to scattering from air that is trapped on the paper surface and in the paper structure.
- Increasing ultrasonic intensity passing through to the receiver, due to the pores and capillaries filling with the penetrating liquid (less air to scatter the signal)
- Decreasing ultrasonic intensity passing through to the receiver, due to decreasing elasticity of the fibers as paper is moistened

According to Gigac, et al. the decrease of ultrasonic intensity is governed mainly by a decrease in the elasticity of the swelled fibers, and air being pressed into the largest pores of the paper structure. (Gigac, Stankovska, & Kasajova, 2011). In Figure 4, the SC sheet results are the two leftmost curves, one for side A and one for side B. This indicates that the SC sheets, and not the target paper machine samples, saturate with water fastest. If water absorption rate were the driving force to lateral web movement, the target paper machine samples should show the fastest reduction in ultrasonic intensity.

For the IPA/water solution Gigac, et al. found that a liquid displaced air from the pores and penetrated the uncoated papers immediately. Air was more slowly displaced from coated papers, due to the higher number of fine pores in the coating on the paper surface. Figure 5 shows that again, the SC sheets had a faster decrease in ultrasonic intensity than the coated sheets. Gigac, et al. suggests that measuring the time at which ultrasonic intensity drops to 95% for the 16% IPA solution gives information about the number of fine pores in the paper surface; a longer time to t95 means more fine pores and fewer large pores. Measuring the ultrasonic intensity at 70 ms (USI70) for the distilled water solution gives information about surface roughness, with higher USI70 values representing higher surface roughness, more trapped air, and therefore longer time for the liquid to penetrate the fiber surface (Gigac, Stankovska, & Kasajova, 2011). The t95 (distilled water) and USI70 (IPA/water solution) measurements for the selected samples and are shown in Table 2.

The t95 results indicate that there are small differences in the quantity of fine pores on the paper surface. The maximum value is 1.031 seconds for one side of the target PM sheets. The second side of the same sheets has a value about ½ that of the first side indicating fewer fine pores and more larger pores. This make some sense as the target paper machine is a Fourdrinier machine with one side having a more closed surface than the other. Coating holdout and therefore fine pore concentration is likely to be higher on one side than the other. The grade 3 sample had t95 values of 0.224 and 0.258 s on the two sides indicating fewer fine pores than the target PM sheet. This could be possible depending on the pigments used in the coatings. Different pigments give different pore size distribution. In (Gigac, Stankovska, & Kasajova, 2011), the t95 test results ranged from a minimum of 50 ms for uncoated sheets to 14.8 s. In the results of this work, the range of measurement for t95 was 98 ms to 1.031 s, not nearly the large range that Gigac was working with. The uncoated papers that were tested by Gigac are not specified as to what calendaring treatment they were subjected to and it is possible no supercalendered sheets were tested. Kettle et al. found that for supercalendered papers, large size pores dominated absorption rate in short times (<1 s) but smaller pores dominated at longer times (Kettle, Matthews, Ridgway, & Wagberg, 1997). Supercalendering reduced large pores so that mostly small pores remained. In the papers under test in this work, all have been supercalendered, either with or without coating, and it is evident that large pores are not a major contributor to absorption rate as measured by Emtec..

One issue with relating the Emtec results to printing results may be that, with the Emtec test, the paper sample and test liquid are under low pressure, whereas in printing the paper and water is subjected to a high-pressure pulse as it passes through the printing nip. Because it was expected that water penetration will proceed faster at noncoated sheets, and at lower basis weights, for this test the samples with most variable basis weight and pore structure were selected. In any event, the ultrasonic intensity measurement did not discern a difference between the papers for predicting lateral web movement.

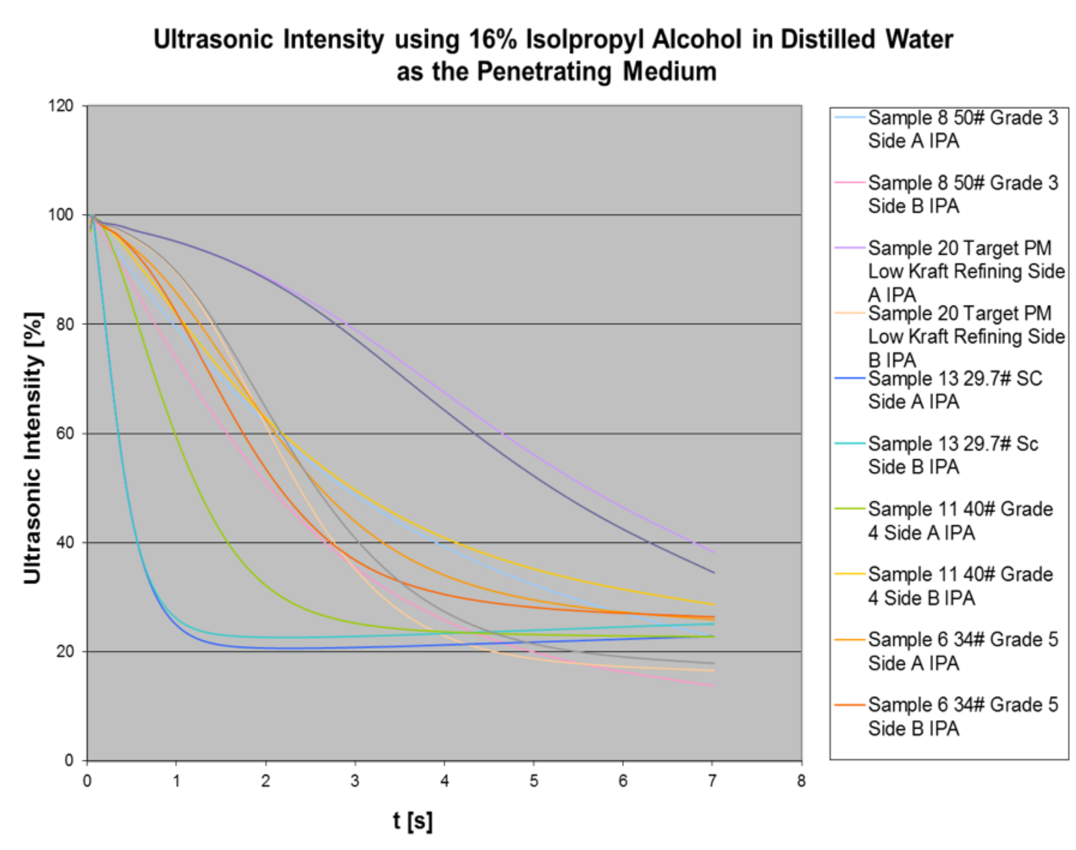

Figure 5. Ultrasonic absorption of selected samples with 16% IPA in water as the penetrating liquid.
Inset shows same curves during the first 0.5 seconds. (50 # means 50 lbs/3300ft2, or 74 gsm).

Table 2. Ultrasonic intensity measurements according based on (Gigac, et al. 2011) for selected samples. Basis weight [gsm] is expressed as #.

Sample ID	13	13	20	20	8	8	11	11	6	6	3	3
Sample Description	29.7# SC Side A	29.7# SC Side B	40# Target PM Low Kraft Refining	40# Target PM Low Kraft Refining	50# Grade 3 Side A	50# Grade 3 Side B	40# Grade 5 Side A	40# Grade 5 Side B	34# Grade 5 Side A	34# Grade 5 Side B	40# Target PM Coating Trial Side	40# Target PM Coating Trial Side
USI70 (Water),%	99.765	99.998	99.971	99.893	99.950	99.952	99.836	99.973	99.966	99.912	99.874	99.942
t95 (16% IPA), s	0.099	0.098	1.031	0.595	0.248	0.224	0.258	0.384	0.445	0.428	1.031	0.617
USI 70 refers to ultrasound intensity 70 ms after test start. t95 refers to time elapsed to reach 95% of max ultrasound intensity												

Machine direction (MD) tensile strength and cross-machine direction (CD) tensile strength of the samples were measured at 50% RH, 23°C (TAPPI standard conditions) and the ratio of MD/CD tensile strength was reported as Tensile Ratio. For this test, samples were selected that were known to suffer from lower fiber orientation. Fiber orientation is largely governed by the j/w ratio, (j/w- Ratio of headbox jet velocity to forming fabric velocity) and the degree to which the initial alignment produced as the fibers touch the forming fabric can be captured. In gap forming paper machines, the stock jet is trapped between the two forming fabrics almost immediately and the fibers are not free to move relative to each other. In this way, the orientation of the sheet can be controlled. In Fourdrinier paper machines, the stock jet is not trapped between forming fabrics. The fiber mat is purposely agitated on the forming table to aid in dewatering. It is quite difficult to attain high levels of fiber orientation on Fourdrinier paper machines. Tensile Ratio is an indicator of fiber orientation (Niskanen, Kajano, & Pakarinen, 1998, p. 37). A plot of tensile ratio for the available papers is shown in Figure 6. Only SC (supercalendered) sheets or samples for which base papers from coated sheets were available were measured. What is immediately evident is that the trial papers, both from this round of testing and previous samples for which base papers were available, have the lowest tensile ratio. All trial papers had some degree of weave whereas none of the competitive sheets, coated or uncoated, had any degree of weave.

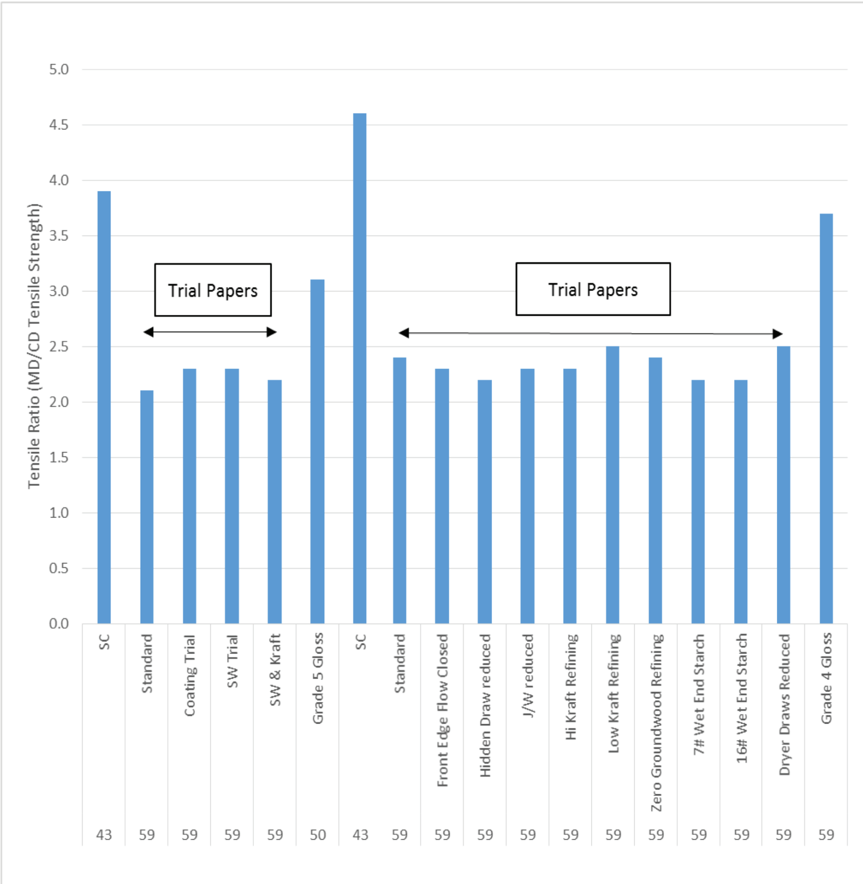

Figure 6. Fiber orientation in various test sheets as measured by tensile ratio.

Conclusions

The purpose of the work was to determine the papermaking factors affecting the lateral web movement on a HSWO printing press. The lateral web movement on the target printing press is caused by lateral forces in the drying section (from right to left of press direction). The target paper machine experiences more lateral movement than other papers, most likely due to lower web tension between the last printing unit and the chill section of the printing press, that is, through the drying section. The lateral forces in the dryer have more effect on webs with lower web tension. The target paper machine produces a Fourdrinier sheet and is expected to absorb water very quickly, at least on one side. The fast absorption rate was expected to cause a larger reduction in tensile stiffness, in the time between printing and drying, for the target PM than for other papers. Absorption rate testing showed that SC papers absorb water faster than the target PM, yet suffer no lateral movement during printing. The reason for lower web tension in the target paper machine web is most likely due to lower fiber orientation. Fibers oriented in the direction of stress have reinforcement from the cellulose microfibrils. During printing, the matrix softens to some degree due to the addition of water. The stiff microfibrils serve to reinforce the matrix and prevent movement. Fibers oriented in the cross direction do not have this reinforcement. Therefore, a less oriented sheet has less reinforcement from the microfibrils and is more susceptible to movement of the matrix. Thus, the fiber orientation in the paper was found to be the most important factor affecting lateral web movement on printing presses.

References

1. Emtec Electronic GmbH. (2002, 02 21). Emtec Measuring Method to Study the Quality of Paper and Process Liquids, their Interaction and its Influence to Converting Processes.
2. EMTEC Measuring Systems. Emtec Electronic GmbH.
3. Emtec Electronic GmbH. (2005, 02 28). Surface & Sizing Tester EST12.2 Operating Instructions. 56(3), 363-370. Emtec Electronic GmgH.
4. Gigac, J., Stankovska, M., & Kasajova, M. (2011). Interactions between offset papers and liquids. Wood Research, 56(3), 363-370.
5. Kajonto, I., & Niskanen, K. (1998). Dimensional Stability. In K. Niskanen, Paper Physics (pp. 222-259). Helsinki: Fapet Oy.
6. Kela, L., & von Hertzen, L. (2007). Printing Press Runnability. KCL 0526370.
7. Kipphan, H. (2001). Drying Methods. In H. Kipphan (Ed.), Handbook of Print Media (pp. 166-179). Berlin Heidelberg: Springer Verlag.
8. Lindblad, G., & Furst, T. (2001). The Ultrasonic Measuring Technology on Paper and Board. Kista: Lorentzen & Wettre.
9. Niskanen, K. (1998). Rheology and moisture effects. In K. Niskanen, Paper Physics (pp. 260-283). Helsinki: Fapet Oy.
10. Per-Olav, T. (1995). Water uptake in newsprint during offset printing. TAPPI, 78(1), 155-16.
11. Retulainen, E., Niskanen, K., & Nilsen, N. (1998a). Bonding. In K. Niskanen, Paper Physics (pp. 70-76). Helsinki: Fapet Oy.
12. Shields, G. (2015). Web Weave Trials Sep 23, 2015. Unpublished results.

George Shields

George Shields, M.Sc., UPM North America, Director of Technical Customer Service

george.shields@upm.com

Alexandra Pekarovicova

Alexandra Pekarovicova, PhD., Professor, Western Michigan University, Kalamazoo, MI

a.pekarovicova@wmich.edu

Paul D. Fleming

Paul Daniel Fleming III, Ph.D., Professor, Western Michigan University, Kalamazoo, MI

dan.fleming@wmich.edu

Jan Pekarovic

wJan Pekarovic, Ph.D., Western Michigan University, Kalama-zoo, MI