Optimizing Press Section and Paper Machine Performance

Louis Gentile
Regional Manager
Lorentzen & Wettre USA, Inc.
Alpharetta, Georgia

Andy Kahra
Paper Machine Specialist
Lorentzen & Wettre USA, Inc.
Alpharetta, Georgia

ABSTRACT

The objective of this paper is to show the importance of using the necessary tools to collect, evaluate and take the necessary actions to improve and optimize not just head box but overall paper machine performance to produce quality paper at low operating costs. It has been proven that one cannot rely on on-line dry end scanners alone, since the information obtained is too late in the process to make necessary changes. Since certain problems exist in the press section, such as moisture streaks, that on-line sensors cannot measure, a study was performed on the wet end of the paper machine using dedicated tools to detect these issues.

By adjusting certain head box parameters and addressing some of press section problems we were to achieve substantial cost savings. This study focuses on the impact as well as the results from the adjustments performed on the paper machine. The study was performed at a mill experiencing among other issues wrinkles, which resulted in both machine and winder run ability issues thus affecting production. Wrinkles, which typically originate from uneven moisture profiles in the press section, can actually worsen with increased machine speed. A higher than normal frequency of web breaks, which may be caused by severe wrinkles or by improper pressing, was also a major concern. This paper will point out recommendations for further improvements to machine efficiency and additional economic benefits that can be achieved by proper utilization of these tools.

APPLICATION

This study was performed on a fourdrinier machine with a hydraulic headbox and a 3-nip conventional press section using 70% hardwood, for good printing characteristics, and 30% bleached chemical softwood, for added strength. Grades produced were mainly for printing and writing applications. Some of the major issues included low edge CD stiffness, both diagonal and MD/CD curl and image deletion. Diagonal curl was a result of a non-symmetric fiber orientation profile as shown in Figure 6. MD/CD curl was due to a high MD/CD ratio; i.e., a high jet/wire speed differential, as shown in Figure 8. Image deletion was due mostly to cockling (buckling), which is a result of poor moisture profiles as shown in Figures 14 and 15.

Wrinkles were, however, the major concern. This slowed down the machine thereby lowering entire production. To correct this problem the mill decided to use a spreader roll, which caused excessive spreading of the sheet thereby reducing both its stretch and stiffness. Another attempt was to increase the draws in the press section. The results were the same. The actual root cause of the wrinkles was wet/dry streaks, or wet/dry zone variations in both the forming and pressing areas. The fact that the machine used a steam box to correct for moisture variations actually over-compensated the problem. As an outcome, not only did the wrinkles remain, but also the sheet lost bulk, which created an uneven caliper profile.

Valuable tools are available today that provide insights into the paper machine. The tools used to troubleshoot the machine approach and wet end headbox and forming table, as well as the press section were a TSO (Tensile Stiffness Orientation) ultrasonic instrument, a Scanpro PressTuner portable moisture instrument shown in Figure 3, and a Scanpro FeltPerm portable water permeability instrument shown in Figure 2, with a flow chart operation diagram shown in Figure 3A.

The following are brief descriptions of the tools:

TSO - a non-destructive and rapid test method in determining both stiffness and fiber orientation of the sheet. An ultrasonic signal is generated by a pulse generator clock, and sent from each of the eight-sender/receiver pairs to a software program with the following results shown in Figures 1 and 1A.

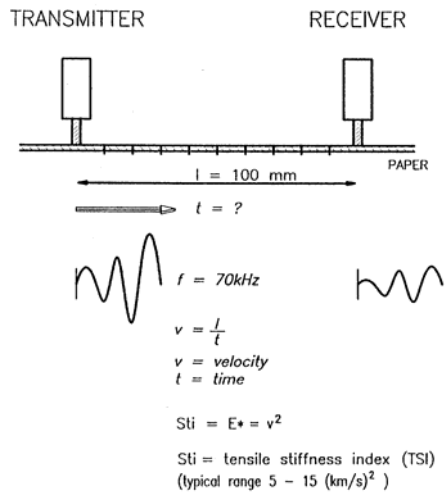

Figure 1

The numerical approximation is then used to transform the signals into a polar diagram shown in Figure 1 b.

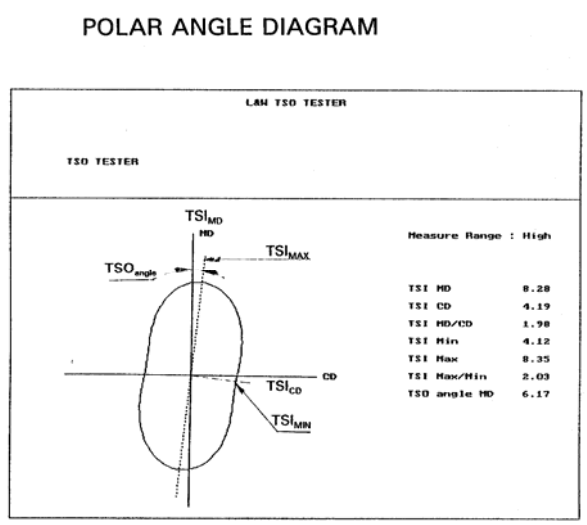

Figure 1A

The key values for the papermaker to evaluate in the above polar plot in Figure 1A are:

- TSO angle: the orientation of the maximum TSI (tensile stiffness index) as an angle deviating from the machine direction, known as the tensile stiffness orientation.
- $TSI_{MD/CD}$: the ratio between the TSI in the machine direction and the TSI in the cross direction. The ratio is a measure of the anisotropy of the sheet to be compared to the classical strength properties. The lower the ratio the more identical is the orientation of both the top and bottom sheet layers; i.e., the squarer the sheet.
- TSI_{MD} : the tensile stiffness index measured in the machine direction of the sheet.
- TSI_{CD} : the tensile stiffness index measured in the cross direction of the sheet.

Scanpro FeltPerm Water Permeability Instrument - Permeability profiles show the condition of the fabric in actual operation. They should therefore be performed on a regular basis to track the felt performance over time. The FeltPerm portable water permeability instrument is shown in Figure 2 has the following characteristics:

- Measures according to TAPPI TIP 0404-43
- Measures the openness (void volume) of the press fabric
- dynamic measurement
- Measurement relates to the hydraulic flow resistance in the press nip
- Best indicator of felt's condition

Figure 2 - FeltPerm

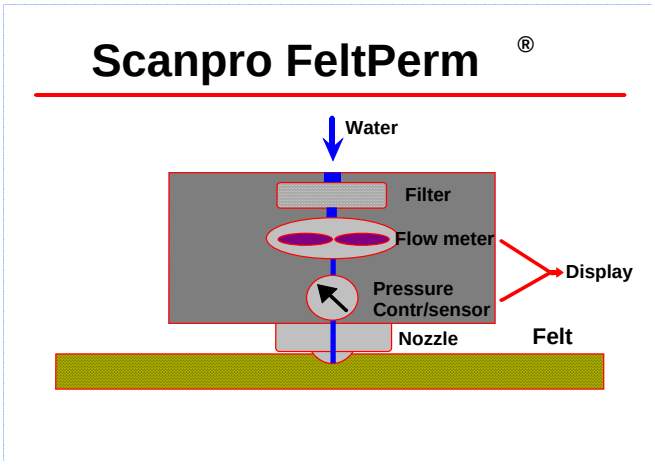

Figure 2A – FeltPerm Flow Chart Diagram

Figure 3 –PressTuner Moisture Instrument

PressTuner Moisture Instrument - Moisture measurements show problems induced by press rolls, showers and suction boxes as well as the fabric. The PressTuner moisture instrument is shown in Figure 3.

- The basic sensor is a dual-frequency cavity resonator, excited by a low power microwave signal
- The microwave field is sensitive to the dielectric constant of the material that is being measured
- The dielectric constant of water being about 75 and the dielectric constant of fiber and felt structure is about 3
- The measurement is 25 more times sensitive to water
- The measurement is reported in gsm

OBJECTIVE

The study was to establish a baseline for optimum machine performance using the above-mentioned tools. The first action was to evaluate headbox consistency, which measured 0.85. As the consistency was decreased, the wrinkles actually got worse while cockling remained. Additional adjustments were done in the press section to improve CD moisture profile after pressing.

A closed felt, or plugs in the felt, is the result of poor high-pressure shower maintenance. Felts must be permeable to water and need to be open, even when compressed. If not, by repeated compressions in the press nip, felt compaction will occur as substances such as pitch, fines and fillers fill the void space within the felt structure. The end result is wet streaks as shown in the profile in Figure 15 and poor CD moisture as shown in Figure 14. Due to these wide streaks there is a potential for both sheet crushing and sheet marking. Felt maintenance is a way to optimize the felt dewatering capability, which in turn will improve machine runnability and sheet quality.

These tools will help to optimize felt pressing and dewatering performance, maintain machine efficiency, runnability and product quality, determine the felt cleaning efficacy, and cost-optimize the felt cleaning program.

CHALLENGE

Tests were performed to evaluate headbox performance using the TSO data profiles.

The TSO Angle in **Figures 6 and 7** has two components, fiber alignment and built-in strain and stresses from the paper making process. Most paper grades tend to have an angle of +/- 5 degrees with the mean value at zero. Any deviation from this angle indicates that the headbox is not adjusted to provide a balanced sheet. **Figure 6** shows a very asymmetric profile, pointing out the possibility of more water going to the front edge due to a higher pressure at the front of the headbox. This results in an uneven headbox pressure profile. **Figure 7** shows a more symmetric orientation after adjusting the re-circulation valve.

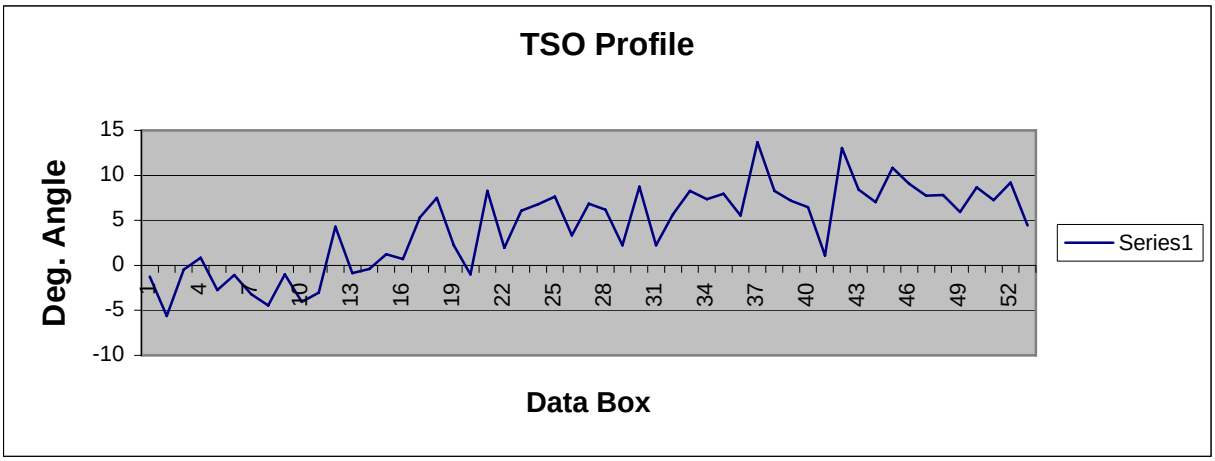

Figure 6 – TSO Fiber Orientation un-symmetric profile

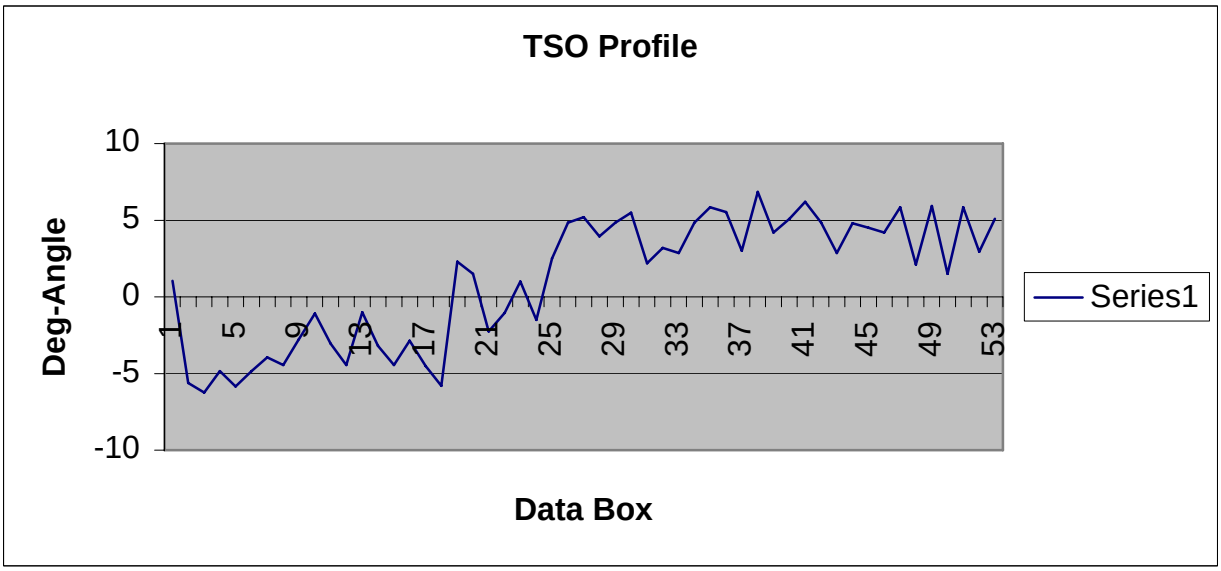

Figure 7 – TSO Fiber Orientation more symmetric profile

The $TSI_{MD/CD}$ ratio in **Figure 8** shows the squareness of the sheet, which is influenced by both the jet/wire speed differential and the l/b ratio. It is the best tool to determine if the paper machine is in a rush or drag mode. Since the profile is above the normal limits the profile shown in **Figure 8** indicates the potential for MD/CD curl. The profile is normally flat on most grades. As the MD/CD ratio is higher than normal the profile shape is too frowned. The streaky felts shown in **Figures 14 and 15** also resulted in a poor TSI MD profile shown in **Figure 10**.

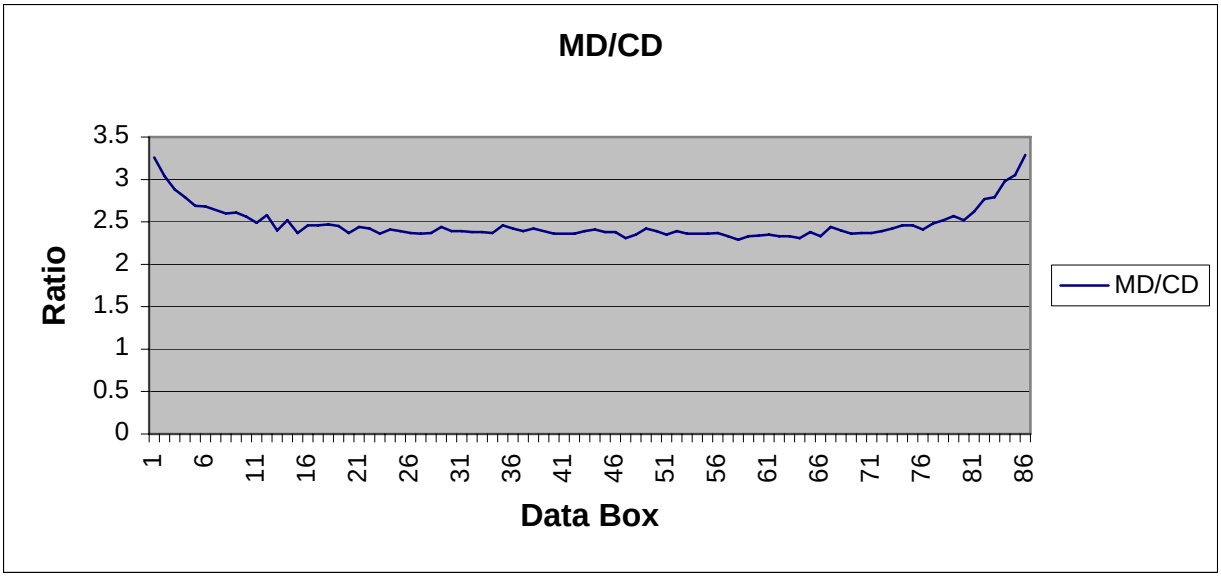

Figure 8 – $TSI_{MD/CD}$ Ratio (Anisotropy - Squareness of Sheet) – Ratio is slightly high

Slightly lowering the l/b ratio from 1.15 to 1.10 and reducing the speed differential by 20 ft/min substantially reduced the MD/CD curl, as shown in **Figure 9.**

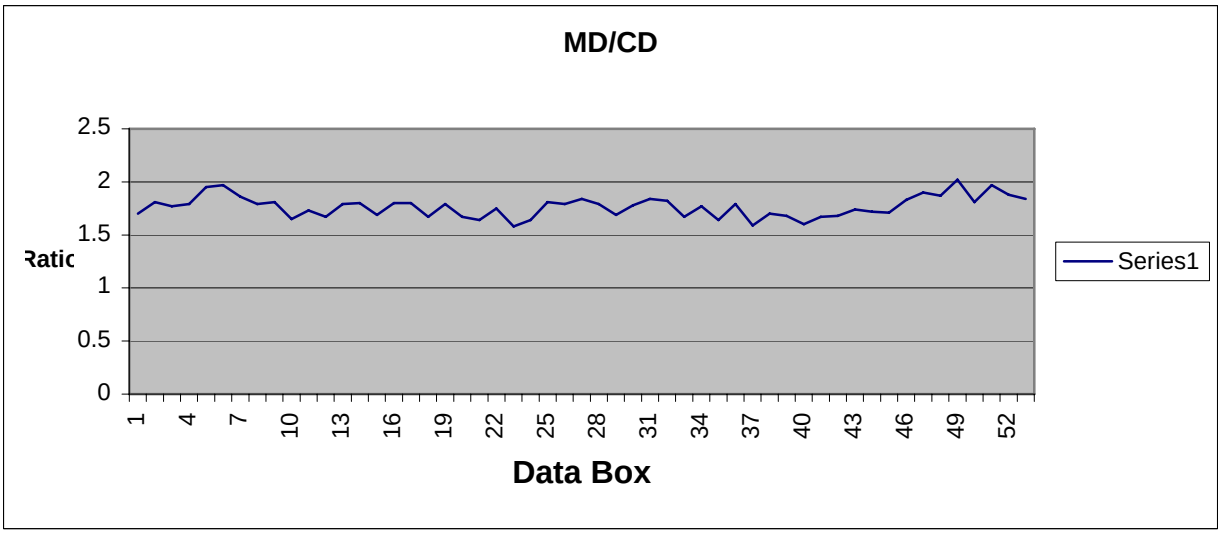

Figure 9 – $TSI_{MD/CD}$ Ratio (Anisotropy - Squareness of Sheet) – a more uniform and flat profile

The TSI_{MD} in **Figure 10** is the elasticity of the paper in the machine direction and is a good indication of runnability. The profile is normally flat on almost all grades. The standard deviation is typically 0.13-0.15. The high variation indicates a streaky sheet due to streaky felts shown in **Figures 14 and 15**, resulting in wrinkles.

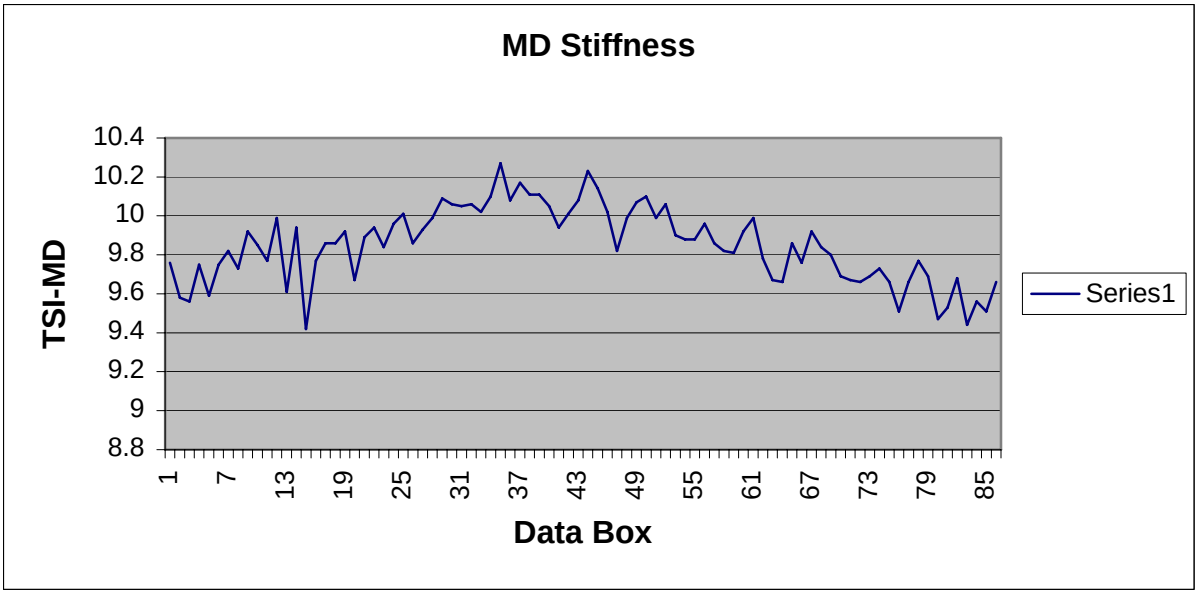

Figure 10 – TSI_{MD} Stiffness – low edges and high variations

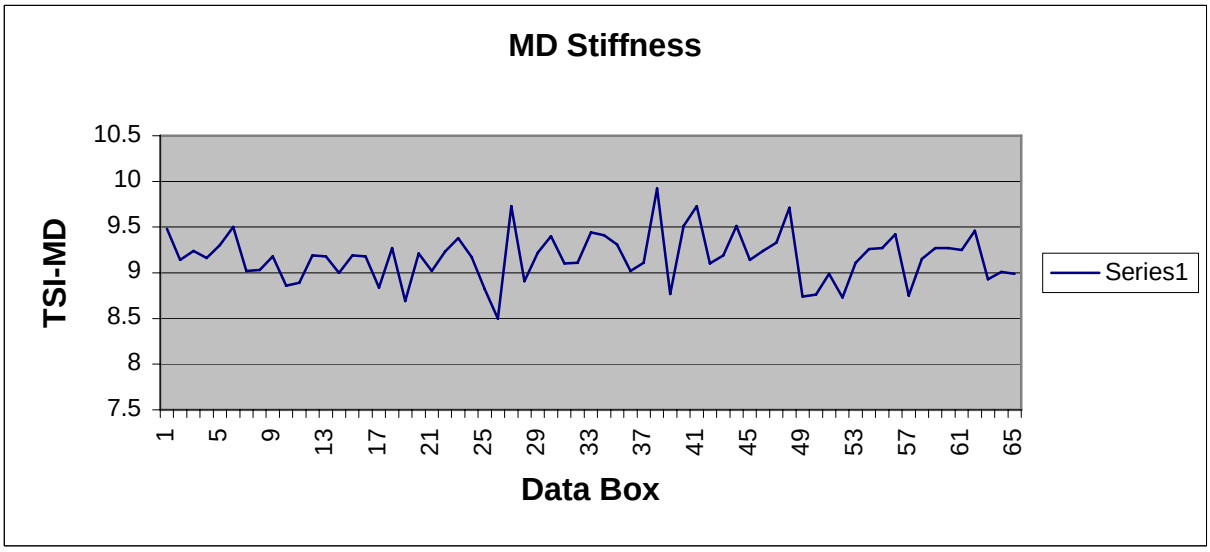

Figure 11 – TSI_{MD} Stiffness – improved edges and lower variations

Figure 11 shows an improved TSI_{MD} profile. This resulted from both the reduced speed differential change of 20 ft/min and the 10 ft draw reduction in the press section. This reduced some of the wrinkles. The impingement angle was increased, or lowering the l/b ratio, which leads more towards pressure forming rather than velocity forming. The end result was a more even MD and CD profile. **Figures 12 and 13** shows the CD profile before and after the adjustments. The changes also improved the low edge stiffness. In addition increasing and decreasing edge bleeds effects were determined and reviewed by the TSO and TSI MD and CD profiles.

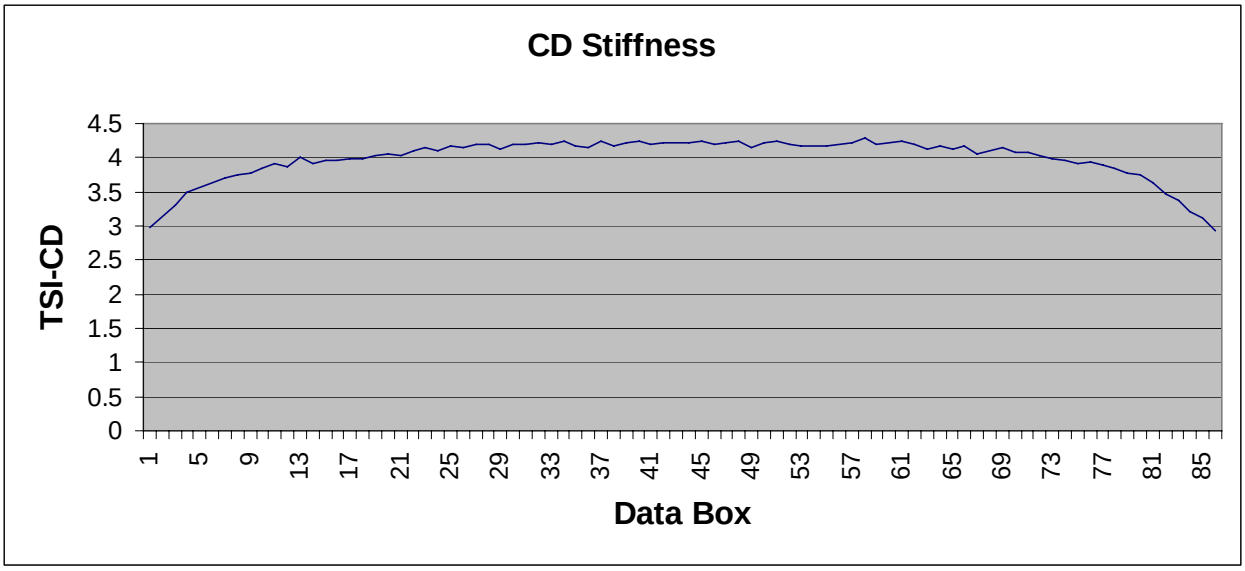

Figure 12 – TSI_{CD} Stiffness before adjustments

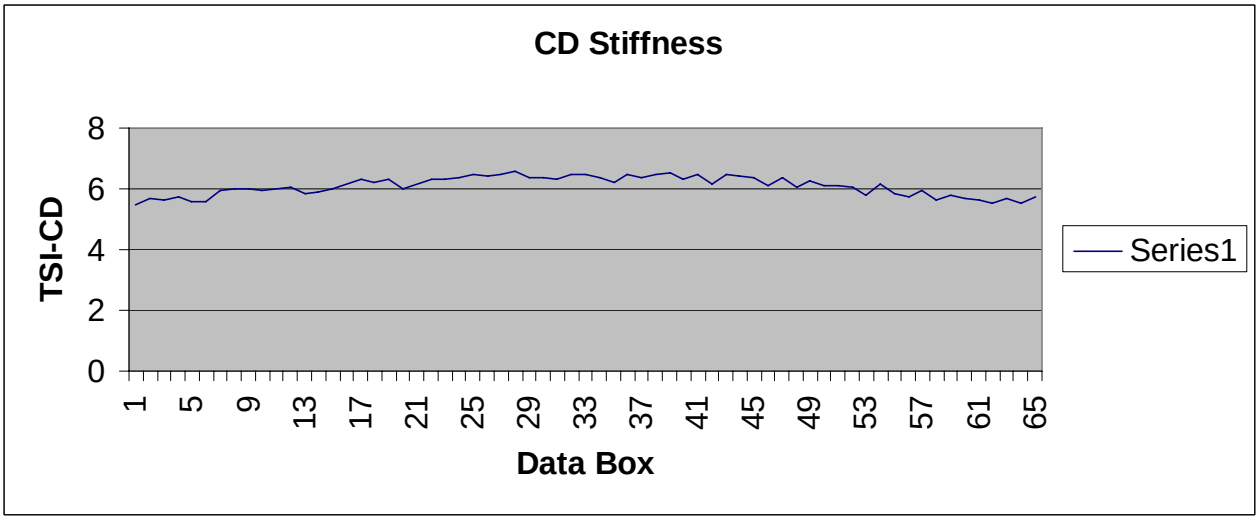

Figure 13 – TSI_{CD} Stiffness after adjustments

To reduce wrinkles even further, additional adjustments with the headbox consistency were performed. Lowering the consistency caused worse wrinkles. Increasing the consistency to 0.95 eliminated most of the wrinkles. Further improvements to cockling were noticed as well as a more uniform moisture and permeability profile as shown in **Figure 16.**

Plugged felts are very common on any paper machine mostly due to plugged shower nozzles. Most high-pressure oscillating showers have proven to be ineffective. This is due to wrong or uneven oscillating speeds causing improper cleaning of the full coverage of the felts. Both the first and second press felts shown in **Figures 14 and 15** respectively were plugged due to poor shower maintenance. As a result, the mill was experiencing paper quality issues including wet streaks and poor CD moisture profile.

The moisture profile indicates higher moisture in the same area where permeability indicates excessive felt filling due to the improperly maintained high-pressure showers. A high moisture and low void volume (plugged felt due to plugged shower nozzles) was also causing sheet crushing and sheet marking.

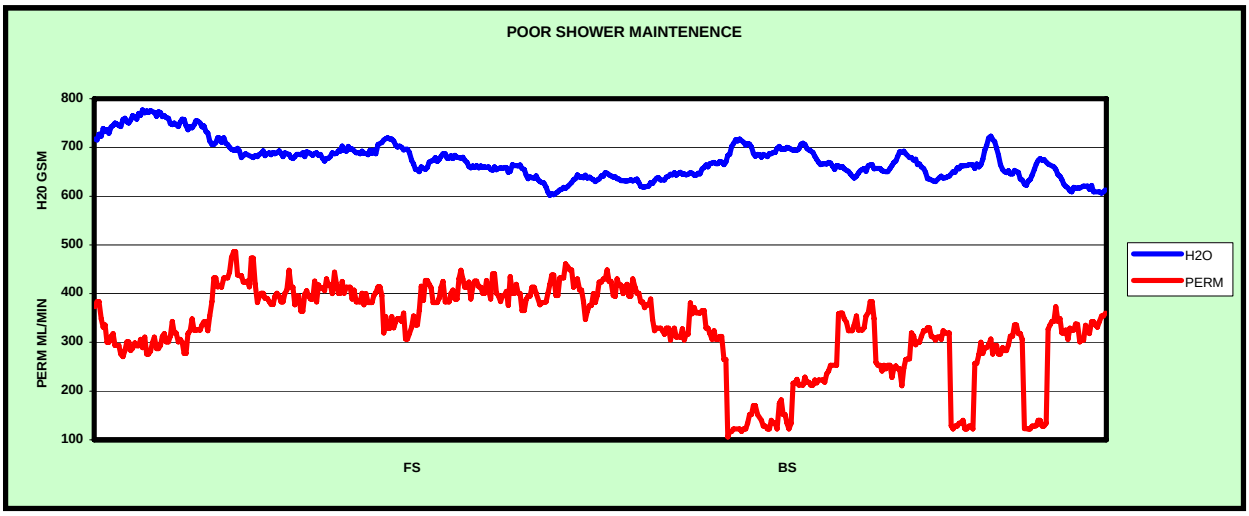

Figure 14 – PressTuner Moisture Scan and FeltPerm Permeability

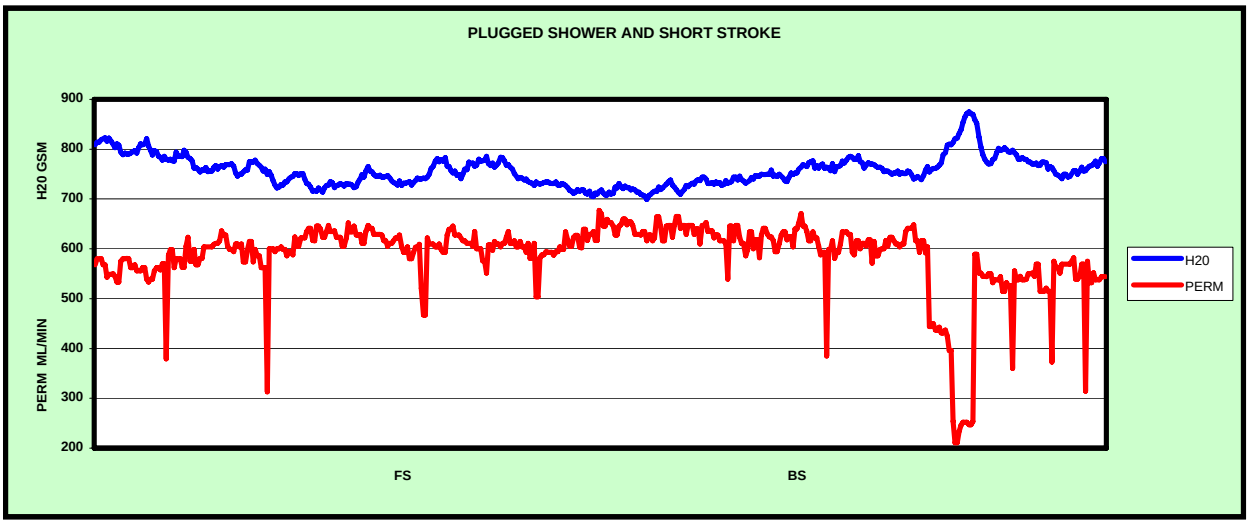

Figure 15 – PressTuner Moisture Scan and FeltPerm Permeability Scan

Many press section problems are seen, or at least, monitored by the scanning moisture gauges at the reel. Unfortunately subsequent over-drying of the sheet can hide moisture streaks induced in the press section. In some cases, improperly adjusted presses can actually cancel out their poor profiles and produce a flat and therefore good profile at the reel. The costs to make flat profiles by masking variations are very high. The final results will show up as deformations of the paper when exposed to changes in relative humidity.

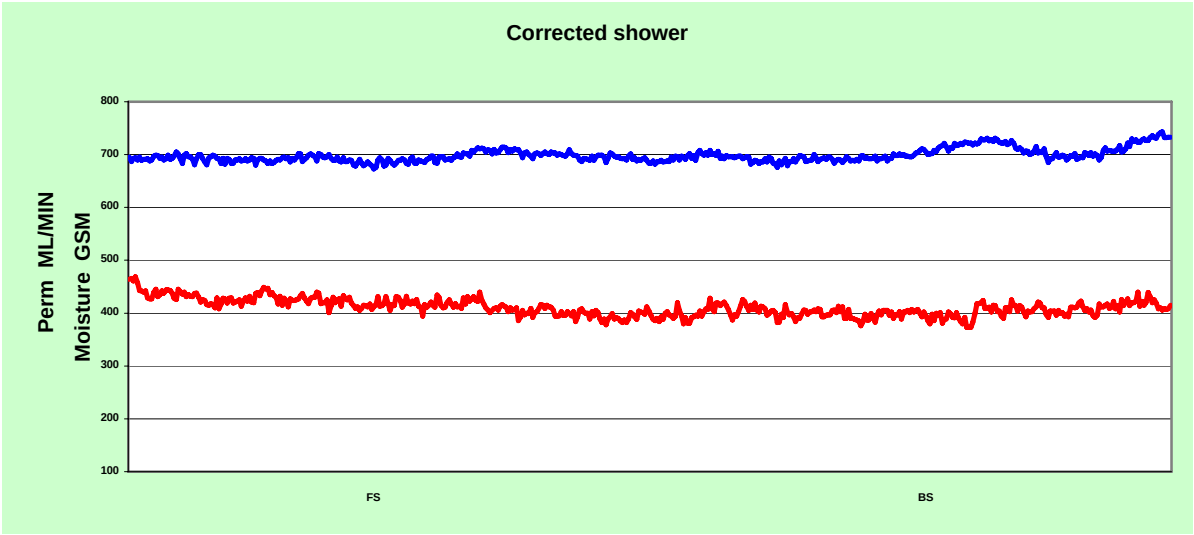

Figure 16 – 1st Press after shower adjustments

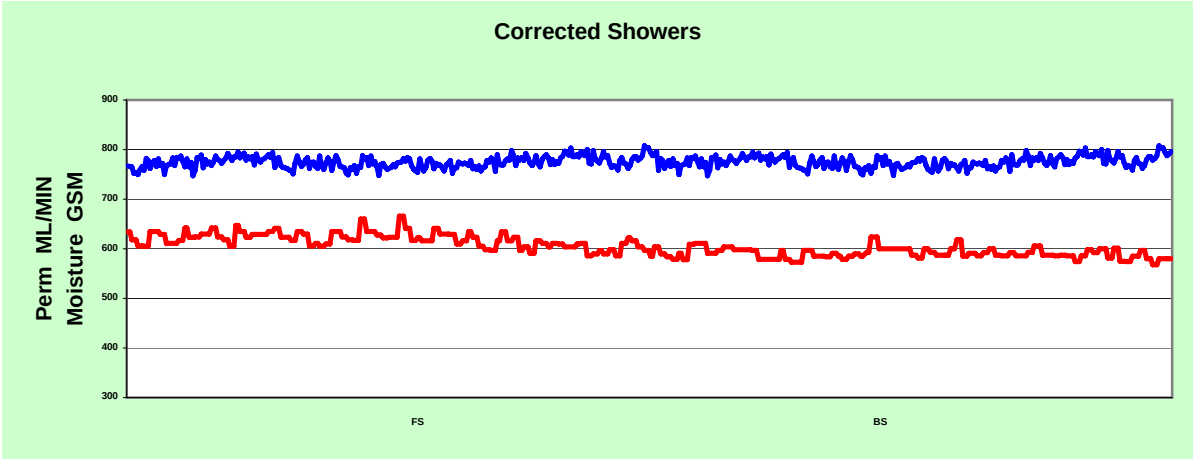

Figure 17 – 2nd Press after shower adjustments

A dramatic improvement shown in both **Figures 16 and 17** is a result of a change in showers. The mill installed brush type showers along with a filtered water supply. Synchronization of the high-pressure showers to paper machine speed greatly improved the fabric profiles eliminating all major plugging and streaks. Proper shower applications along with a good chemical cleaning program will greatly improve felt and press section performance.

In this study both felt water permeability and felt moisture instruments proved poor felt performance. The TSO profiles showed that by proper adjustment of the orientation profile and MD/CD sheet squareness, sheet quality was greatly improved. In general, an efficient press section will better consolidate the sheet thereby improving density, strength and surface smoothness. Using the moisture meter in a CD mode located moisture streaks, which also showed up on the TSI_{MD} profile in **Figure 11.** The felt water permeability meter can determine problems that may otherwise be overlooked by paper testing and other dry end gauging measurements. High pressure oscillating needle showers specifically used for cleaning the felts will typically cause these streaks. In the case of plugged showers, there is a very good chance that a filled streak can lead to sheet crush and runnability problems. Repeated compressions in the press nip eventually lead to felt compaction, pitch, fines and fillers filling the void space within the felt structure. As a result of these changes, the felt water permeability gradually diminishes to the point that the

water removal from the felt cannot readily escape into the grooves or drilled holes of the press roll. High hydraulic pressure, which is created in the press nip under these conditions, can result in sheet crushing, vibration and inadequate water removal from the web. A routine felt maintenance program of frequent moisture and permeability profiling during the life of the felt is one of the ways to improve press section performance and, sheet quality. Permeability loss is another effect that will cause dewatering problems and require changing the felts prematurely. One of the cost saving benefits achieved from this study was a 25% improvement in felt life and consequently, lower operating costs.

CONCLUSION

To reduce machine downtime, extend press felt life and schedule efficient felt changes, close and consistent monitoring of several variables is essential. Measurements should be performed frequently and regularly to establish a baseline for a good working paper machine. The insight gained during this study has provided better knowledge of the process and what is required to produce a quality product. Results from the study provided the papermaker a better understanding of potential wet end problems as well as possible solutions. It also proved that while maintaining a low uniform moisture level in the press reduced both wet and dryer breaks.

Additional work is to be performed to further optimize the process. A more consistent paper machine optimization program consisting of the re-alignment of jet delivery, press section monitoring and felt measurement and analysis will result in direct cost improvements, including:

- Increased machine efficiency
- Reduced energy consumption
- Lower felt and chemical costs by optimized chemical cleaning program
- Improved felt life and quality/performance over it’s lifetime
- Fewer and better planned machine stoppages
- More uniform paper quality
- Fewer rejects
- More satisfied customers, and potentially additional customers

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Using the Necessary Tools to Troubleshoot and Optimize Press Section and Machine Performance

Louis Gentile
Regional Manager
Lorentzen & Wettre, USA

Andy Kahra
Paper Machine Specialist
Lorentzen & Wettre, USA

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Application

Paper Machine: Fourdrinier
Hydraulic Headbox
3-Nip Press Section

Furnish: 70% hardwood
- printing characteristics
30% bleached chemical softwood
- added strength

Grades: Uncoated Copy/Offset

Objective

- Optimize headbox performance
- Optimize press section
- Improve machine efficiency, runnability and product quality
- Determine felt cleaning efficacy
- Cost-optimize felt cleaning program

Problems: - Diagonal Curl
- Poor Stiffness
- Wrinkles

Tools: - TSO Ultrasonic instrument shown in Figure 1 (a,b,c,d,e)
- FeltPerm Permeability Meter shown in Figure 2 (a,b).
- PressTuner Moisture Meter shown in Figure 3.

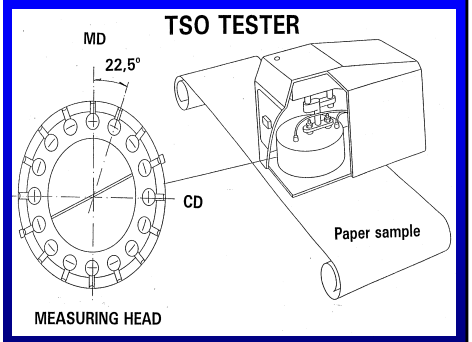


Figure 1a

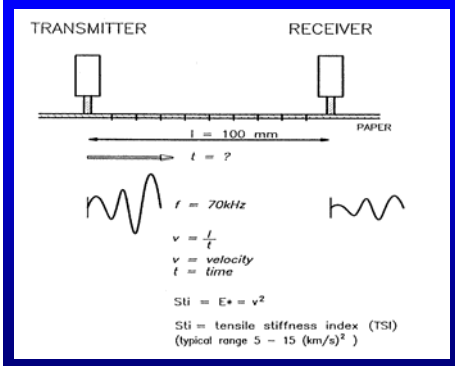


Figure 1b

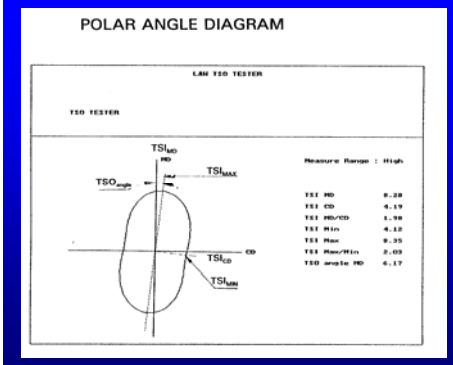


Figure 1c

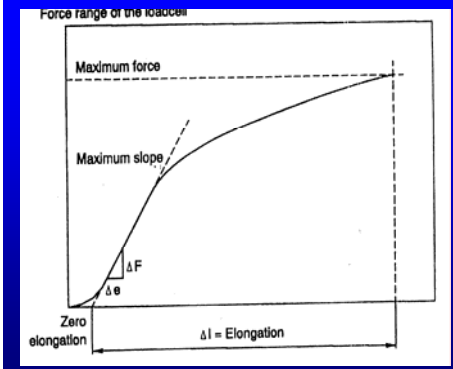


Figure 1e

TSO Key Values

- TSO polar angle: fiber orientation as an angle deviating from the machine direction. Also known as the tensile stiffness orientation.
- $TSI_{MD/CD}$: measure of the anisotropy, or the squareness of the sheet.
- TSI_{MD}: machine direction tensile stiffness
- TSI_{CD}: cross machine tensile stiffness

Optional Calculated Properties:

- Hygro-expansion (Inversed proportional to TSI CD)
- Stack/Lean
- Twist/Curl
- RCT/SCT
- Bending Stiffness

Ultrasonic Advantages

- Outstanding tool for PM optimization
- Data given in CD Profile
- Non Destructive
- Indication of paper performance under dynamic conditions
  i.e converting or printing.

Parameters To Be Monitored

- Key to have a stable process

- **Stuffbox Freeness**
- **Headbox Consistency**
- **First Pass Retention**
- **Vertical Slice Opening**
- **Horizontal Slice Position**
- **Refining**
- **Extended Nip Pressure**
- **Calendar Loading**
- **Felt Moisture**
- **Felt Permeability**
- **Ply Split**
- **Machine Speed**
- **Wire Speed**
- **Headbox Head**
- **Rush/Drag**
- **L/B Ratio**
- **Chemical Addition**
- **Basis Weight**
- **Broke Flow**
- **TSO Sheet Balance**
- **TSI-MD/CD Ratio**
- **Strength properties**
- **Stiffness**
- **Roughness**

Optimization Adjustments

TSO and TSI MD/CD: Headbox (1st step)

- Re-circulation
- Slice lip/Apron
- Rush/Drag
- L/B Ratio
- Tubing
- Edge Injectors/Bleed valves
- Wire curlers/Deckle boards

TSI MD and TSI CD: Press, (Dryer) (2nd step)

- Press loads
- Press crowning
- Plugged showers
- Suction boxes
- Compacted felts
- Felt Condition
- Total draw
- Steam distribution
- Refining

FeltPerm Permeability Meter

- Measures according to TAPPI TIP 0404-43
- Measures openness (void volume) of the press fabric
- Dynamic measurement
- Measurement relates to the hydraulic flow resistance in the press nip
- Best indicator of felt's condition

Figure 2a

Scanpro FeltPerm®

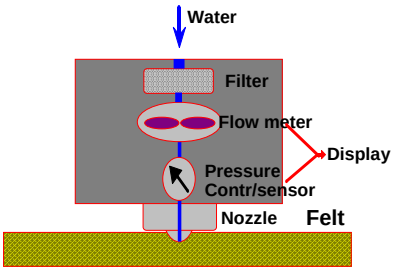


Figure 2b

PressTuner Moisture Meter

- The sensor is a dual-frequency cavity resonator, excited by a low power microwave signal.
- The microwave field is sensitive to the dielectric constant of the material that is being measured.
- The dielectric constant of water being about 75 and the dielectric constant of fiber and felt structure about 3.
- The measurement is 25 times more sensitive to water.
- The measurement is reported in GSM

Figure 3

Actions using the TSO instrument

1st Step:

TSO instrument: align asymmetric headbox using the re-circulation valve with results shown in Figures 4 and 5

Result: a balance sheet

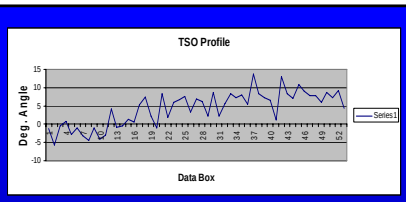


Figure 4 - Asymmetric TSO profile

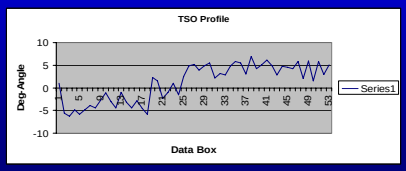


Figure 5 - Symmetric TSO profile

Actions

2nd Step:

- Lower the L/b ratio from 1.15 to 1.10 as well as reducing jet/wire speed differential by 20 ft/min

Results: a more flat and less variable TSI MD/CD ratio, i.e. a more square sheet eliminating the potential for diagonal curl, as shown in Figures, 6,7 and 8.

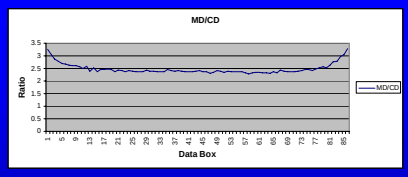


Figure 6 - A slightly high $TSI_{MD/CD}$ ratio

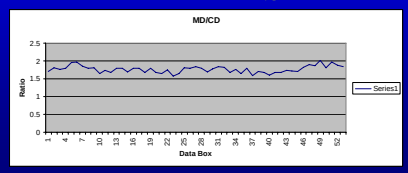


Figure 7 - A more uniform and flat $TSI_{MD/CD}$ ratio

Dimensional Stability – Stack/Lean

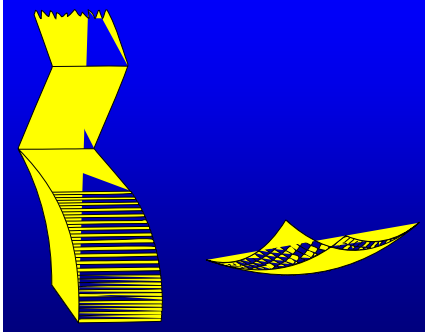


Figure 8 – an example of diagonal curl and twist-curl

Diagonal Curl Formula

Diagonal Curl = 57.3 x ARCTAN [0.5 x (SQRT ($TSI_{max/min}$) – (1/SQRT($TSI_{max/min}$)))] x SIN [2 x ABS ((TSO_{angle})/57.3)] X 4.3

Note: The target for good runnability should be 13 or less.

Formula developed by Xerox (North America) and the Pulp and Paper Institute of Canada (Paprican)

Actions

3rd Step:

- By reducing the jet/wire speed differential and in addition reducing the draw by 10 ft in the press section
- Lowering the L/b ratio, or increasing the impingement angle, which leads to more pressure forming rather than velocity forming.

Results: a more flat and less variable TSI MD profile thus reducing some of the wrinkles as shown in Figures 8 and 9. The changes also improved the low edge stiffness as shown in Figures 10 and 11.

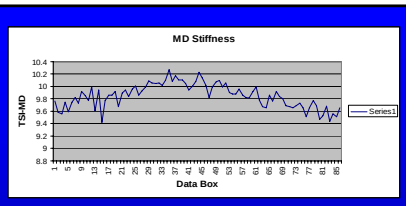


Figure 8 – TSI_{MD}:low edges and high local variation

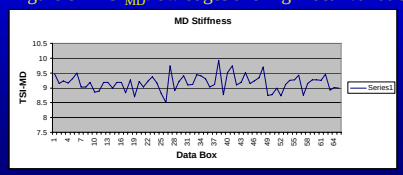


Figure 9 - TSI_{MD}:improved overall profile

Baggy Edges

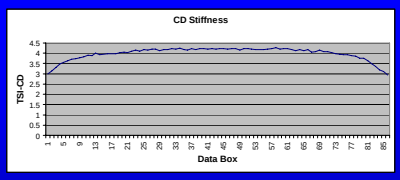


Figure 10 - TSI_{CD}:before adjustments

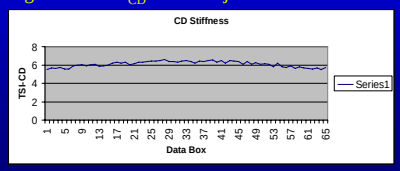
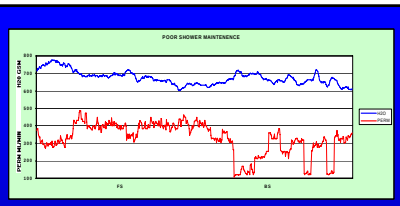


Figure 11 - TSI_{CD}:after adjustment

Actions using both the PressTuner Moisture and FeltPerm Permeability Meters

Profiles shown in Figure 12 indicate higher moisture in the same area whereas the permeability indicates felt filling due to improperly maintained high-pressure showers.

Results: sheet crushing
Sheet marking



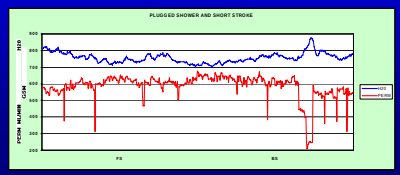


Figure 12 - Moisture and Permeability Profiles

Actions using both the PressTuner Moisture and FeltPerm Permeability Meters

1st Step - synchronize high pressure showers to the machine speed.

Figures 14 and 15 show a dramatic improvement after a change in the showers.

Actions using both the PressTuner Moisture and FeltPerm Permeability Meters

After synchronizing the high-pressure showers to the paper machine speed using the calculation in Figure 13.

2nd step - change showers to brush type as well as installing a filtered water supply.

Results: a dramatic improvement in the fabric profiles thus eliminating all major plugging and streaks, as shown in Figures 14 and 15.

Oscillation Speed Calculations

Low Frequency Oscillators
Optimum Traversing Speed (.040" JET)

$$\frac{\text{FPM X .040}}{\text{FT.}} = \text{Traversing Speed (inches/minute)}$$

FPM = Machine Speed (feet/minute)
FT. = Fabric Length
.040 = Water Jet Width (inches)

Example: Machine Speed – 2000 FPM
Fabric Length – 65 feet

$$\text{Oscillation Speed} = \frac{2000}{65} \times 0.040 = 1.23 \text{ inches/minute}$$

Figure 13 – Oscillation Speed Formula

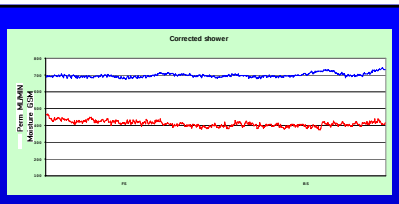


Figure 14 - 1st Press after shower adjustment

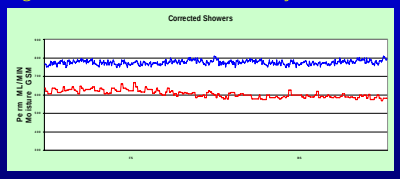


Figure 15 - 2nd Press after shower adjustment

Conclusion

- Increased machine efficiency
- Reduced energy consumption by approximately 5%
- Lower felt and chemical costs by optimized chemical cleaning program
- Improved felt life and quality/performance over it's lifetime
- Fewer and better planned machine stoppages
- More uniform paper quality
- Fewer rejects
- More satisfied customers, and potentially additional customers

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