

Press Section Performance Optimization Through Technology

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Abstract

One of the major challenges in press section performance is choosing the right press fabric for the press system. Previously, roll cover and press felt engineers worked independently on a press system and, at times, they did so to the detriment of performance to the paper machine.

Typically, press dewatering is a blend of nip and uhle box dewatering. Paper machine vintage, speed, press load and grade structure dictate the split of each dewatering type. Choosing the proper press fabric and roll cover design is critical to optimize machine performance and paper quality.

Through the development of modular press fabrics and predictive modeling tools, Voith engineers now can work together to maximize sheet dryness and optimize press section dewatering. This paper will step through the process of identifying the opportunity of press system improvement through the selection of press roll covers and press felts utilizing modeling techniques.

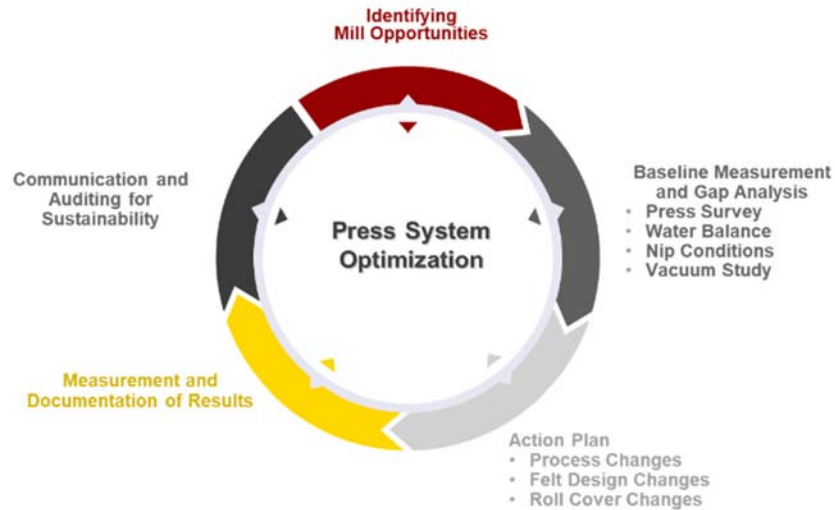
Overview

There are many papers on the theoretical aspects of pressing with the majority citing P.B. Wahlstrom and his model of pressing and this article will be no different. However, with recent mill closures and the conversion of assets from manufacturing graphical grades, the industry needs a practical approach in looking at the press nip as a system of roll loadings, roll hardness, excess void volume and press felt design that will allow papermakers to maximize their assets.

Viewing press dewatering as a system, press felt and roll engineers have an opportunity to combine the simulation of press impulse and press fabric compression to predict and maximize press solids. Utilizing both roll cover technology and modular press felts, felt and roll engineers can accomplish the goal of maximizing press solids and improving machine run ability. While maximizing press dewatering can improve test properties such as tensile and burst, care must be taken not to hurt other properties such as bulk. To counter this, a systematic approach should be taken.

Figure One below depicts the systematic approach of working through the optimization of the press system. The process starts with identifying the improvement area. This could be the improvement of press exit solids, decreasing the number of wet end breaks, decreasing dryer steam demand, or improving the function of the press system over the life of press fabrics and/or rolls.

Figure 1. Approach to Press Optimization



Once the opportunity is identified, baseline data needs to be collected so that the optimization process can begin. One of the first places to start this process is looking at the press impulse based on the current press configuration.

Press Impulse

Press impulse is defined as the area under the pressure curve of a roll system. It can be calculated simply in one of the two following ways:

$$\text{Press Impulse} = \text{Average Pressure} \times \text{Nip Residence Time}$$

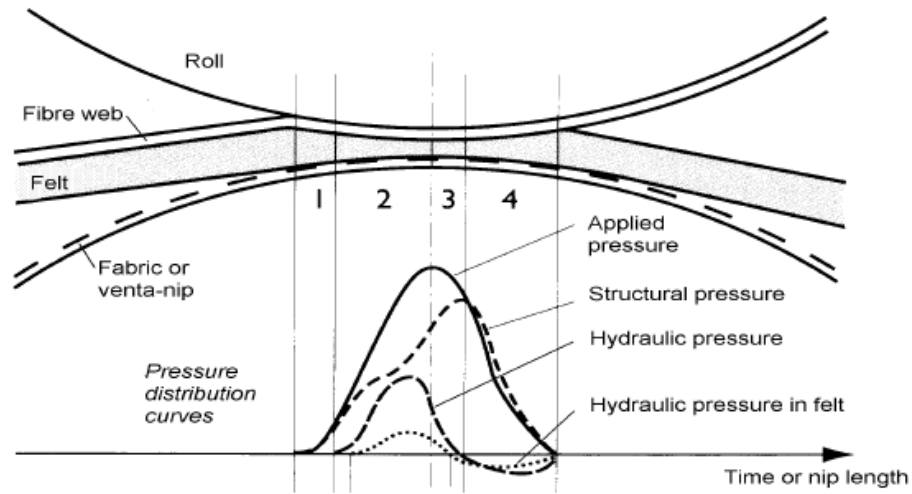
OR

$$\text{Press Impulse} = \text{Nip Load} / \text{Machine Speed}$$

Correct results require that the units of measure must be consistent, either imperial or metric. As can be seen, maximizing press load or increasing the residence time increases the press impulse. Therefore, running press loading at maximum or increasing the nip residence time such as seen in an extended nip press goes a long way to increasing the press impulse. This is important to understand in relation to optimizing press systems and as we look at Wahlstrom's theory of Press Dewatering.

Wahlstrom's model, Figure Two, depicts the accepted four-phase system of sheet dewatering in the press nip. The model holds true for standard roll presses, long nip presses, and extended nip presses.

Figure 2. Wahlstrom's Theory of Press Dewatering[1].



P. Nilsson and K. O. Larsson, "Paper Web Performance in a Press Nip," *Pulp Paper Mag. Can.*, 69, pp. T-438-445, 1968.

During Phase One, the sheet and felt enter the press nip and mechanical pressure is applied. As the sheet enters Phase Two the sheet and felt(s) become saturated and hydraulic pressure develops. Once the hydraulic pressure in the sheet exceeds P_o , water begins to be driven out of the sheet into the press felt and the venting systems of the rolls. Phase Two extends to mid nip or the point of maximum pressure at which time Phase Two transitions to Phase Three. Phase Three begins at maximum pressure and continues to the maximum sheet dryness which is the point where hydraulic pressure reaches zero ($P_h=0$). Phase Four is defined as the expansion of the sheet and press felt as mechanical pressure goes to zero. It is in Phase Four that rewet can occur as the sheet and felt compete for boundary water that exists at the surface of each structure.

Understanding press impulse and Wahlstrom's theory allows for the development of models to predict press exit solids. One such model is the Decreasing Permeability Model (DPM). The equation below describes the calculation of press moisture ratio utilizing the DPM model. [2]

$$m = (m_o - m_e) \left(1 + \frac{An(m_o - m_e)nl}{vW^2} \right)^{\frac{-1}{n}} + m_e + \frac{R}{W}$$

- m_o = moisture ratio before pressing
- m_e = equilibrium moisture ratio
- l = press impulse (nip load divided by speed), kPa.s
- W = basis weight, kg/m²
- u = kinematic viscosity of water, m²/s
- A = specific permeability, g/m
- n = compressibility factor
- R = rewet, kg/m²

Utilizing this model, one can compare the calculated exit solids with the actual measured solids. Table One below utilizes the DPM model to compare the calculated values with measured values of press solids. Except for *Machine 3* the model does provide a good indicator of achievable press solids based upon press impulse.

Table 1. Comparison of Predicted Press Solids vs Actual Solids

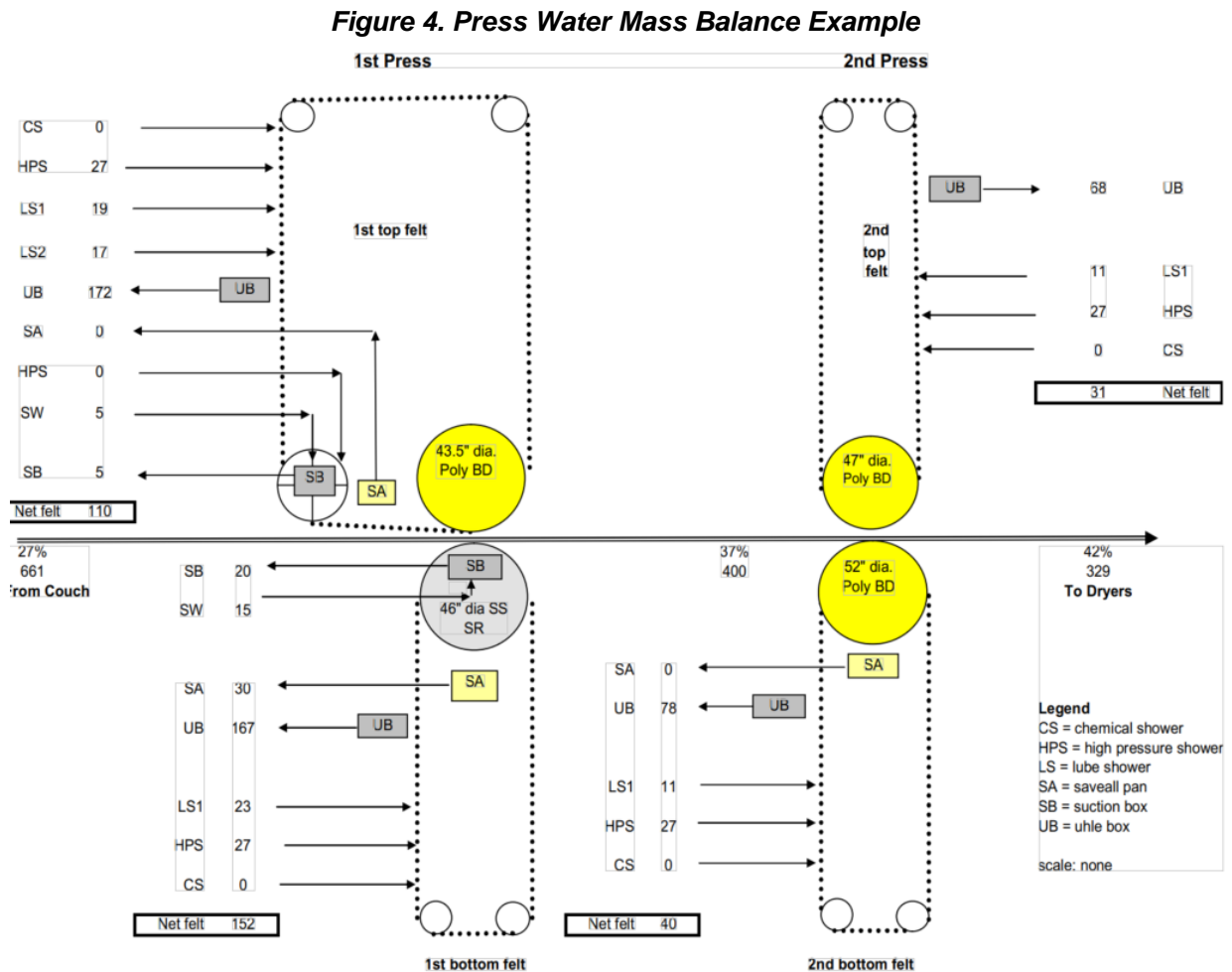
% Press Solids				
	Press Configuration	Grade	Predicted	Actual
<i>Machine 1</i>	Combi/Tandem with Double Felted Straight through 3P	Board and Packaging	43.3	42.8

Machine 2	Combi/Tandem with Double Felted Straight through 3P(Shoe)	Board and Packaging	50.9	49.5
Machine 3	Tri-Nip with Shoe Press	LWC	55.6	48
Machine 4	Tri-Nip with Shoe Press + 4P	Newsprint	48.8	46
Machine 5	Tri-Nip	UFS	39.9	43

What this model does not provide is the impact of press felts and roll selection on underperforming or overperforming press sections. An example would be *Machine 5* where the actual predicted press solids is below the actual measured press solids.

Mass Balance

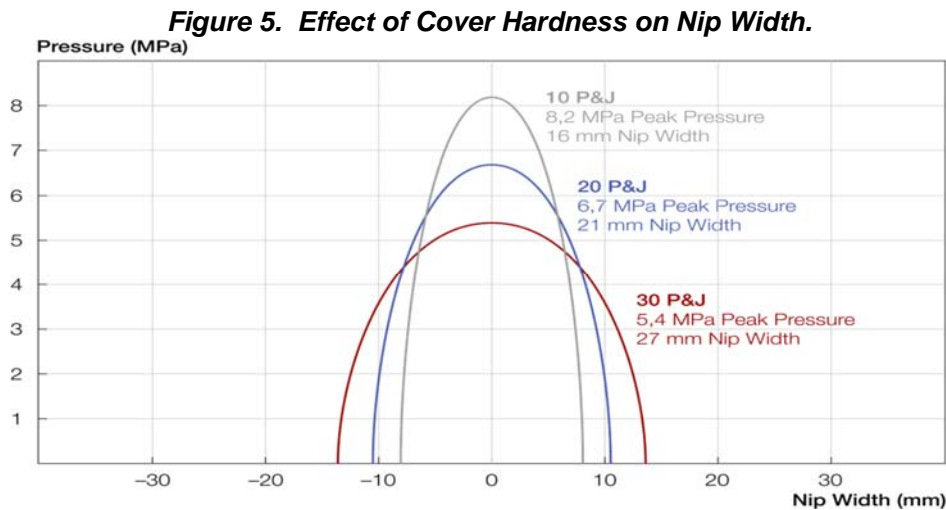
With an understanding of the press impulse and its effect on exiting press solids, the next step is to complete a mass balance to obtain an understanding of how each nip is performing. On modern machines, the measurement of uhle box and nip weir flows is often automated and can be found on the machine's DCS system. However, even if this information is available, it is important to look at all process variables. This includes the water added to the press section through the machine's conditioning and roll systems. Figure Four below shows an example of a mass balance that has been completed on a paper machine including the measurement of all added water in the system.



This data can be compared to TAPPI benchmark standards (TAPPI TIP 0404-47) based on the grade of paper being produced to determine where improvement opportunities exist. Based on the improvement area, one can then begin to look at the design of press roll covers and press fabrics to optimize the press section.

Press Rolls

Selection of press roll venting, roll hardness and cover thickness has a major impact on the nip width and the intensity of the press nip. Figure Five below shows the effect of differing roll hardness on nip width.



In addition to cover hardness, roll open area has a significant impact on press dewatering. If there is not enough excess void volume, sheet crushing or nip rejection can occur.

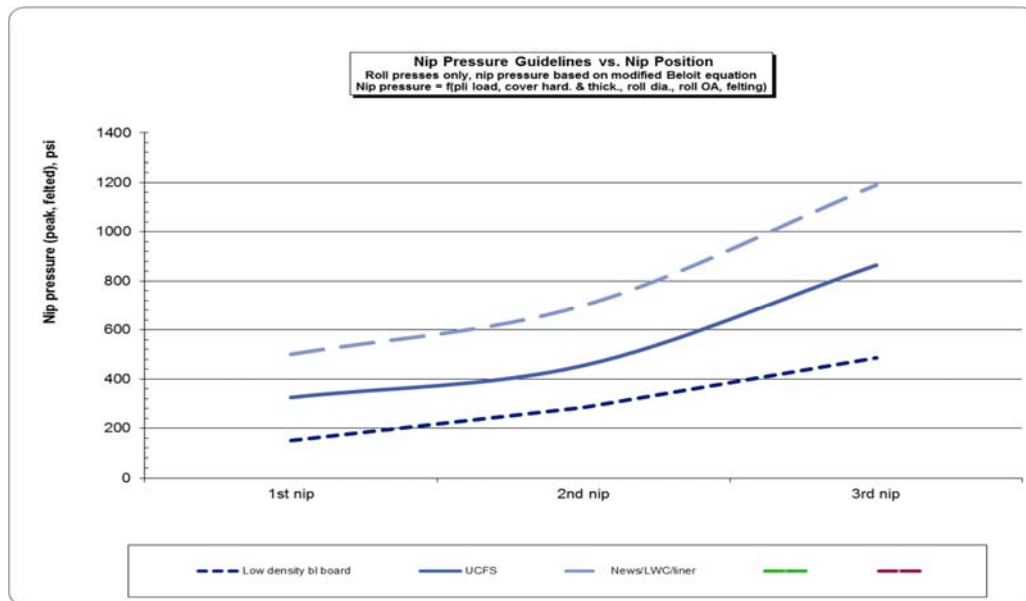
Table 5 below shows a recent improvement in press solids that can be gained through selection of proper open area. This example is on a tri-nip machine recently converted to board and packaging grades. A water balance showed the first nip was under performing. Utilizing a blind drilled and grooved (BDG) strategy for the bottom press roll, the open area of the roll was increased from twenty-eight to forty percent. Water handling of the first press increased from nine to twenty-six percent. While the press exit solids increased from forty-three to forty-five percent.

Table 5. Effect of Open Area on Exit Solids

Press	BEFORE		AFTER	
	Bottom	PU	Bottom	PU
Venting Type	Grooved	SBDG	BDG	SBDG
Roll Hardness(P&J)	4	5	4	5
Open Area (%)	28	41.8	40	41.8
2 nd Press Exit Solids (%)	43		45	
% Water Handling	9	86	26	70

Maximizing dewatering requires that the nip pressure is graduated in consecutive nips. Figure Six below shows a guideline to nip pressures based on press position.

Figure 6. Graduation of Peak Pressures in Consecutive Press Nips.



With the understanding of press pressure graduation, Table 6 demonstrates a recent example where the effect of roll harness on peak pressure and nip width. The initial nip analysis of this board machine showed the 2nd main press only increased the peak psi from the 1st main press by 60 psi. Increasing the roll hardness from 27 to 8 P&J increased the peak pressure change to 170 psi. Additionally, the hardness change reduced the nip width from 1 inch to 0.8 inches. This change allowed the mill to improve sheet consolidation and solids, which translated to reduced breaks and increased machine speeds.

Table 6. Graduation of Press Loadings to Improve Press Solids

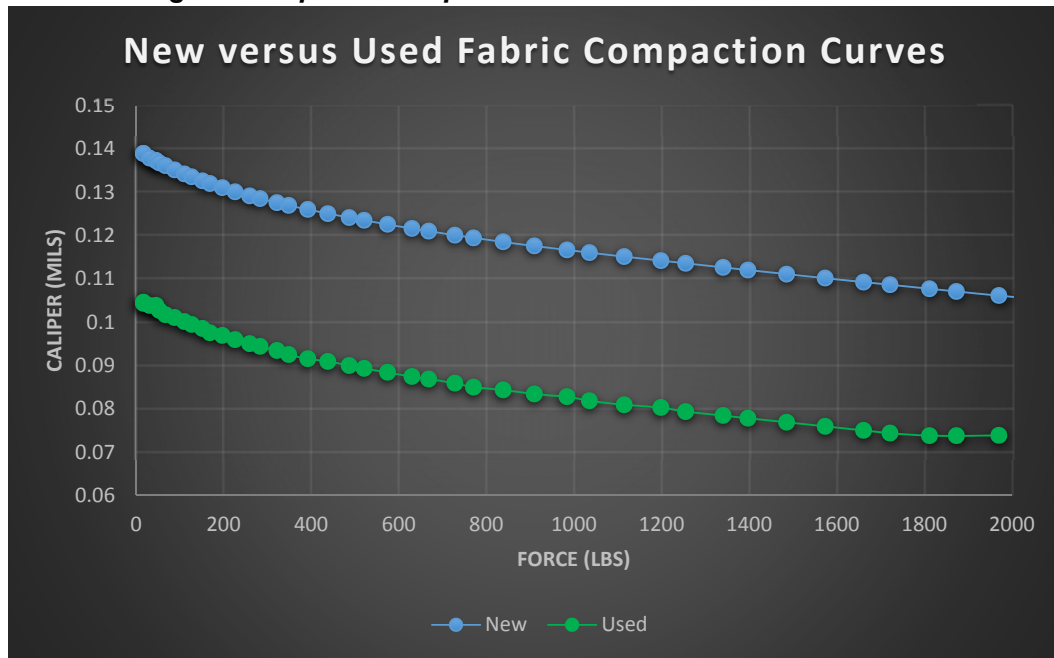
	1st Primary	2nd Primary	1st Main	2nd Main	2nd Main Proposal	3rd Main
Load (pli)	140	230	350	400	400	1500
Cover hardness top roll	123	31	25	27	8	23
Cover hardness bottom roll	8	29	27	13	13	19
Avg Pressure (psi)	69	227.6	338.3	404.2	504.7	757.9
Peak Pressure (psi)	87	319.8	495.2	557.3	673.5	1117.7
Nip Width (inches)	2	1	1	1	0.8	2
Ave Pressure increase ratio			1.49	1.19	1.49	1.88
Peak Pressure increase ratio			1.55	1.13	1.36	2.01

Press Felts

Upon completion of an analysis of a press system and as one looks at press loadings and roll cover technology, press fabrics also need to be analyzed as changes take place to the press nip. Not unlike roll cover hardness, the caliper and compressibility of a press fabric will have a huge effect on the press impulse of a system (please refer to Figure 5 in the Rolls discussion). And not only will changes in fabric type change the shape of the press impulse of a nip system, as a fabric compresses and compacts over life, this will also change the shape of the press impulse from the beginning to the end of press fabric life. Figure 7 below shows the effect of press fabric caliper under load on a fabric position averaging 64 days. Not only is the unloaded caliper lower with the used

sample but the mid-nip caliper is lower as well. This has an effect on the shape of the press impulse curve.

Figure 7. Impact of caliper under load – New vs Used Fabric



With this in mind, the press fabric engineer has many decisions to make when optimizing the press system. Press fabrics come in a variety of configurations, such as endless or seamed. Yarn systems can range from single to cabled monofilament to a mixture of both. And adding batt fiber to the base creates a dewatering medium that has individual unique properties specific to the individual press system. The graph below shows a comparison between a conventionally woven press fabric and one containing new base fabric technology. As can be seen, the new technology bases are thinner and compress more than conventional technology. The increased compression can change where the paper/felt system reaches saturation and will allow the nip system to develop hydraulic pressure earlier in the press nip. As stated during the discussion on Wahlstrom’s theory, increasing early hydraulic pressure has the potential for increased dewatering of the paper structure.

Impact of Base Press Fabric on Compressibility in the Nip

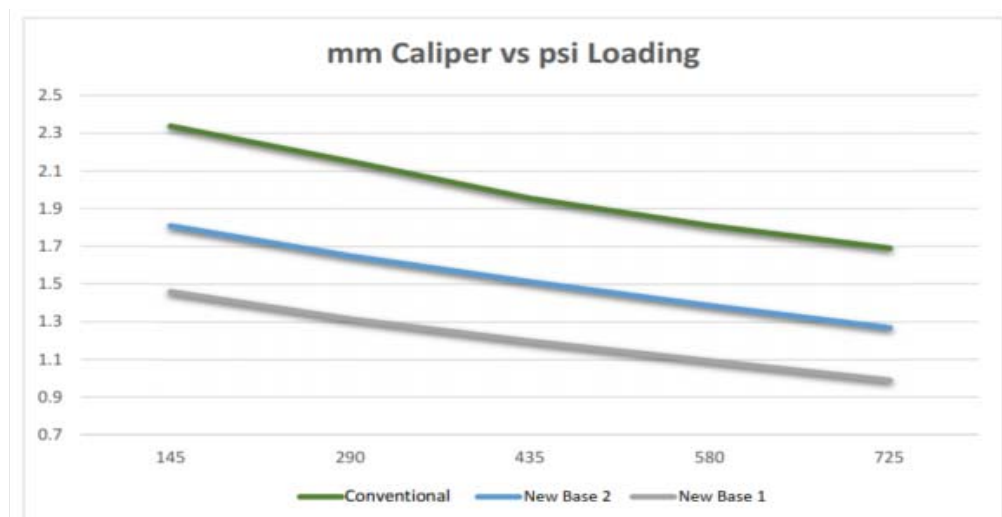


Table 7 provides a comparison of how this new base technology reacts in comparison to conventionally woven base technology. For this comparison, the batt layouts are identical. Base yarns in both felts are identical as well. The only difference is the technology utilized to create the bases for the felts. New technology felts finished twelve percent thinner, which translates to an 8 percent reduction in void volume. The benefit to the papermaker is better dewatering at startup and consistent dewatering throughout the life of the fabric.

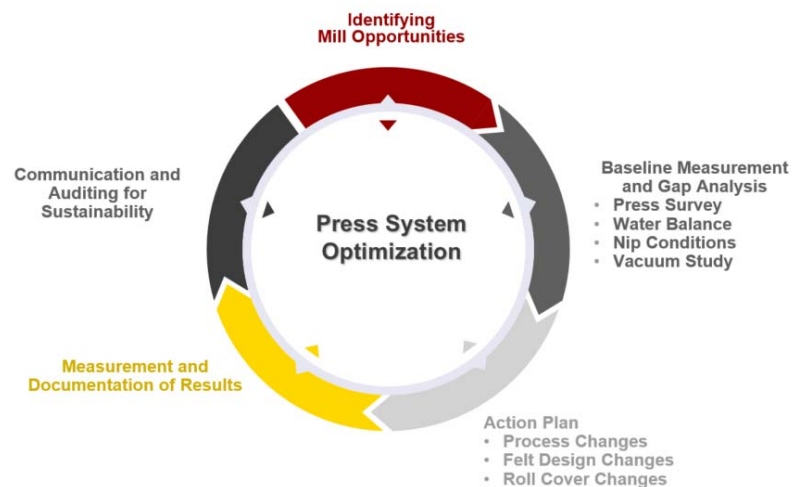
Table 7. Comparison of Calipers based on Base Technology

Base	GSM	Caliper	Void Volume
New Technology	1830	3.62	1019
Old Technology	1858	4.11	1109

Knowing the grade produced, the incoming solids, the press nip type, the press fabric engineer can then take this data to develop the void volume needed for a particular press position.

Conclusion

Optimizing a press section requires a systems approach. One cannot look at just one variable to optimize the system. Rather, the papermaker, the roll engineer and the press felt engineer need to work in conjunction to improve the operation of the press section. Only having clearly defined goals, a review of the current running conditions and measurement of the baseline can one make an improvement. However, once an improvement is made, the process needs to be continually measured to ensure that the system continues to perform. This leads to the identification of other opportunities and areas for improvement.



[1] P. Nilsson and K.O. Larsson, "Paper Web Performance in a Press Nip", Pulp Paper Mag Can, 69,ppT-438-445, 1968

[2] McDonald J. D., Kerekes R. J.(2017).“Pragmatic Mathematical Models of Wet Pressing in Paper Making.” BioResources 12(4), 9520-9537



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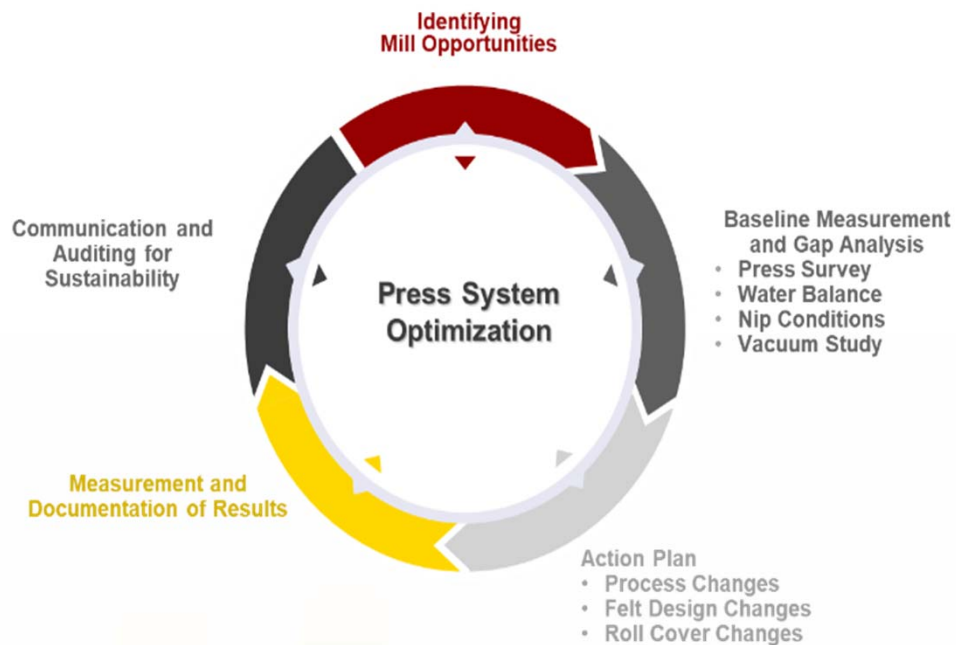
Agenda

- Optimization
 - Why
 - Planning and measurements
- Pressing Dynamics
 - Wahlstrom's Theory On Pressing
 - Press Impulse
 - Mass Balance: Theoretical versus actual sheet solids
- Press Rolls
 - Hardness
 - Venting
 - Press load graduation
 - Sheet solids Improvement

Agenda

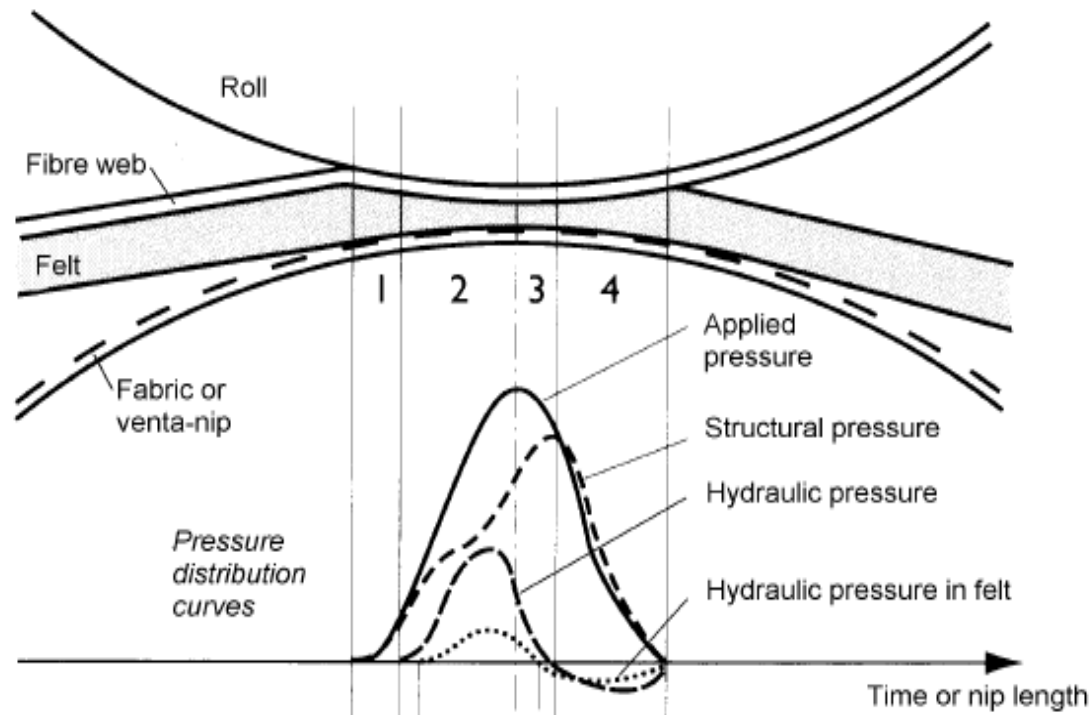
- Press Felts
 - Overview of felt parameters
 - Impact of load on base caliper
 - New versus Used felts, Impact of load
- Summary

Why Press Optimization



- One percent sheet solids into dryer section can reduce energy cost by 5 percent
- Planning is critical for success
 - Identify opportunities
 - Collect base line data
 - Create action plan
 - Clothing change
 - Roll modification
 - Execute plan and monitor results
- Press engineers, rolls and felts, need to work together to achieve the goals

Wahlstrom's Theory On Pressing



- Phases of dewatering
 - Zone 1: Sheet and felt come together and saturation of the system begins
 - Zone 2: Saturation has been reached and hydraulic pressure develops
 - Zone 3: Starts when the system reaches maximum pressure and continues until maximum sheet dryness occurs
 - Zone 4: System expansion occurs and mechanical pressure moves to zero

Press Impulse

$$\textit{Press Impulse} = \frac{\text{Average Pressure} \times \text{Nip Residence Time}}{\text{Nip Load} / \text{Machine Speed}}$$

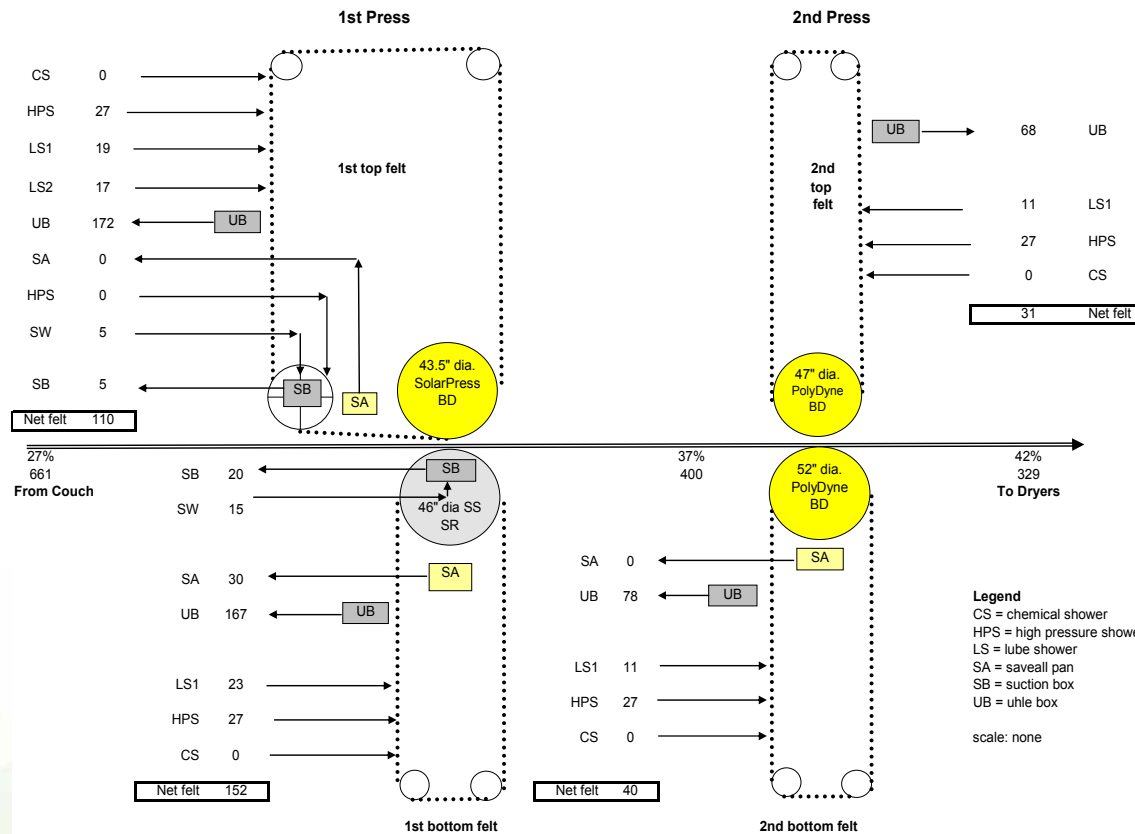
- Maximum water movement in the paper/felt system cannot occur until the system reaches saturation
- To reach maximum sheet dryness, Press Impulse must increase in each successive nip
- Decreasing Permeability Model creates an opportunity to predict sheet solids

Press Impulse: Sheet Solids Predictions

% Press Solids				
	Press Configuration	Grade	Predicted	Actual
<i>Machine 1</i>	Combi/Tandem with Double Felted Straight through 3P	Board and Packaging	43.3	42.8
<i>Machine 2</i>	Combi/Tandem with Double Felted Straight through 3P(Shoe)	Board and Packaging	50.9	49.5
<i>Machine 3</i>	Tri-Nip with Shoe Press	LWC	55.6	48
<i>Machine 4</i>	Tri-Nip with Shoe Press + 4P	Newsprint	48.8	46
<i>Machine 5</i>	Tri-Nip	UFS	39.9	43

- Typically actual sheet solids do not reach the predicted level
- Machine 5 is an anomaly as a result of poor data collection prior to completing the mass balance

Mass Balance



- Mass balances measure the inflow and outflow of the press system
- Accurate measurement of couch solids is critical to the success of the mass balance

Impact of Press Roll Parameters

Figure 4. Effect of Cover Hardness on Nip Width.

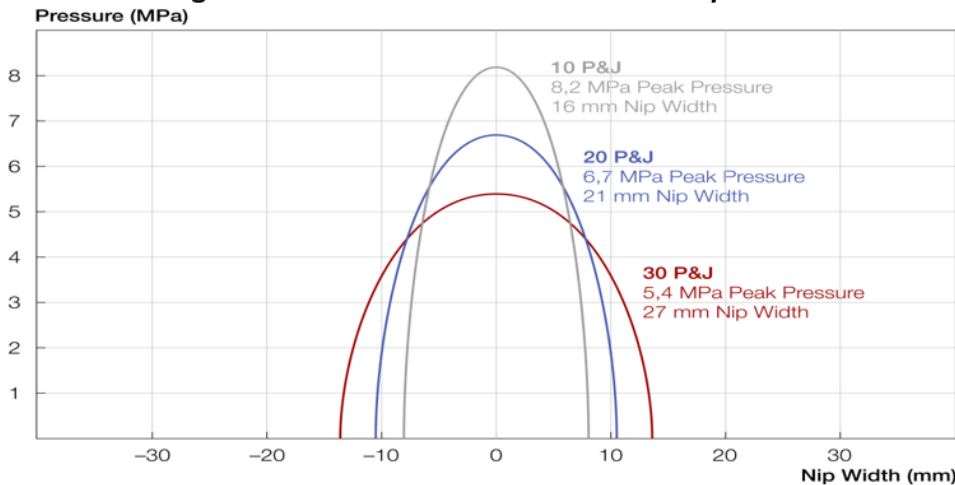


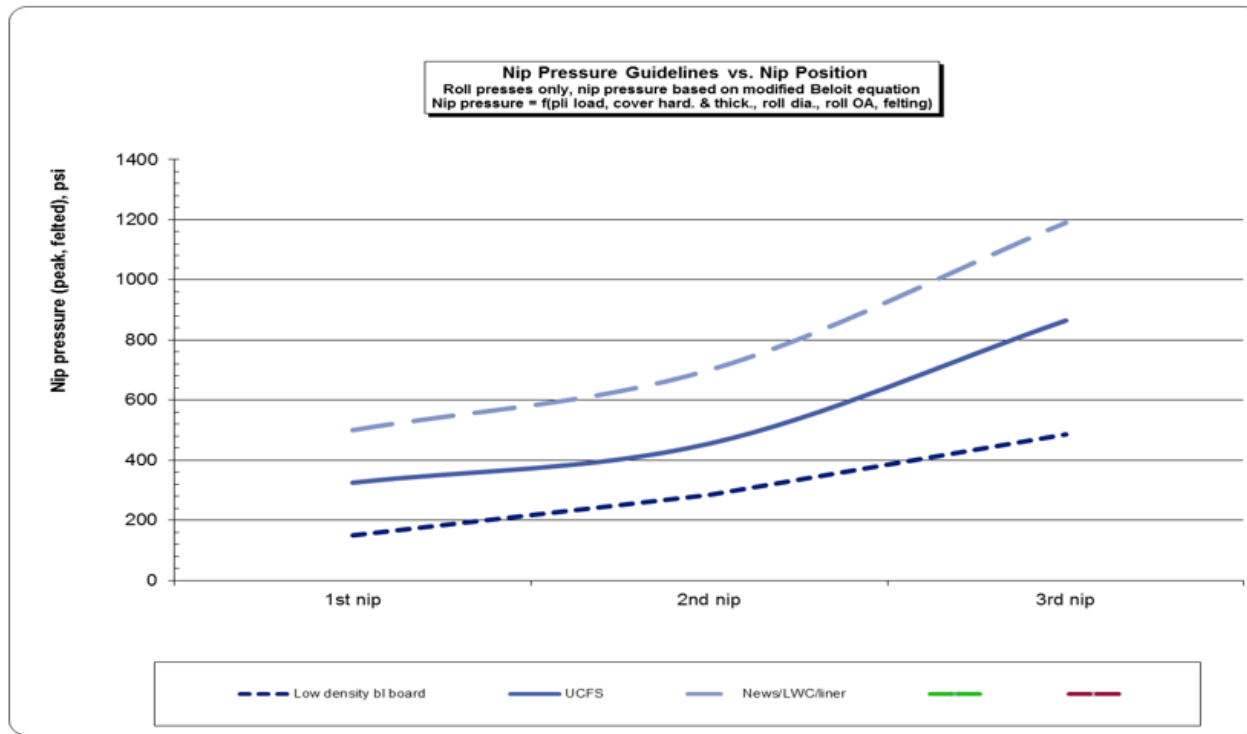
Table 2. Effect of Open Area on Exit Solids

Press	BEFORE		AFTER	
	Bottom	Pickup	Bottom	Pickup
Venting Type	Grooved	SBDG	BDG	SBDG
Roll Hardness(P&J)	4	5	4	5
Open Area (%)	28	41.8	40	41.8
2 nd Press Exit Solids (%)	43		45	
% Water Handling	9	86	26	70

- Roll harness and venting will directly impact sheet consistency
- Roll Hardness
 - Measured in P&J
 - Lower the measurement the harder the cover
 - As the covers softens
 - Nip width widens
 - Peak pressures are reduced
 - Dwell time increases
- Venting Pattern
 - Blind Drilling(BD): water flows to the press felt
 - Grooving(G): water flows through the felt into the voids of the roll

Impact of Press Roll Parameters

Figure 5. Graduation of Peak Pressures in Consecutive Press Nips.



- Water removal requires increasing forces as the sheet dryness increases
- This is true for both the forming and press sections
- Sheet solids increase requires that the peak pressure increases in each successive nip

Impact of Press Roll Parameters

Table 3. Graduation of Press Loadings to Improve Press Solids

	1st Primary	2nd Primary	1st Main	2nd Main	2nd Main Proposal	3rd Main
Load (pli)	140	230	350	400	400	1500
Cover hardness top roll	123	31	25	27	8	23
Cover hardness bottom roll	8	29	27	13	13	19
Avg Pressure (psi)	69	227.6	338.3	404.2	504.7	757.9
Peak Pressure (psi)	87	319.8	495.2	557.3	673.5	1117.7
Nip Width (inches)	2	1	1	1	0.8	2
Ave Pressure increase ratio			1.49	1.19	1.49	1.88
Peak Pressure increase ratio			1.55	1.13	1.36	2.01

- Mill wanted to improve sheet consolidation and machine speeds
- Peak nip intensity increase from the 1st to the 2nd main press was not sufficient
- Increase the top roll hardness of the 2nd main
 - Reduced nip width
 - Increased peak pressure
- 2 percent machine speed increase

Impact of Press Felt Parameters

- Press Felt Parameters
 - Weight, measured in grams per square meter, gsm
 - Caliper, measured in mm
 - Permeability
 - Void Volume, calculated from the weight and caliper of the felt
- Moisture Ratio(MR)
 - Measured felt moisture of the felt before and after uhle boxes, gsm
 - $MR = \text{felt moisture gsm} / \text{felt weight}$
 - Change of felt moisture over the uhle boxes can be used to calculate the amount of water removed by the uhle boxes

Impact of base selection

Impact of Base Press Fabric on Compressibility in the Nip

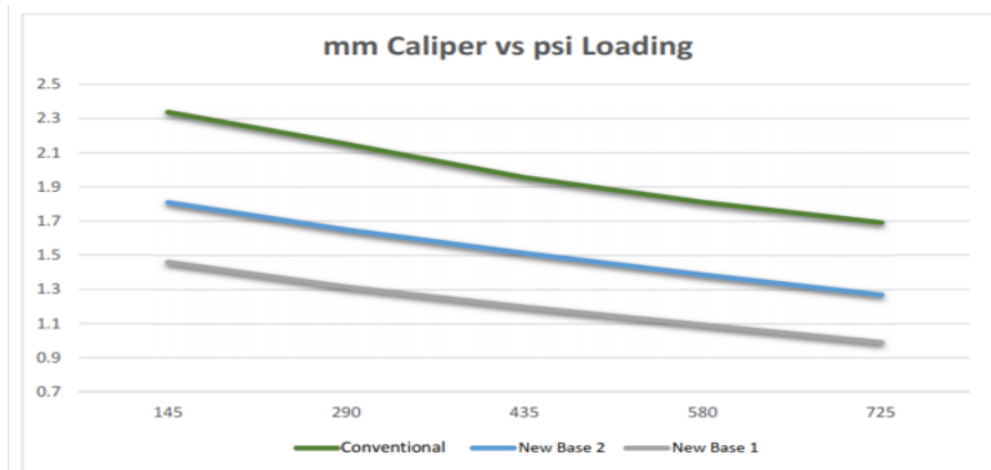


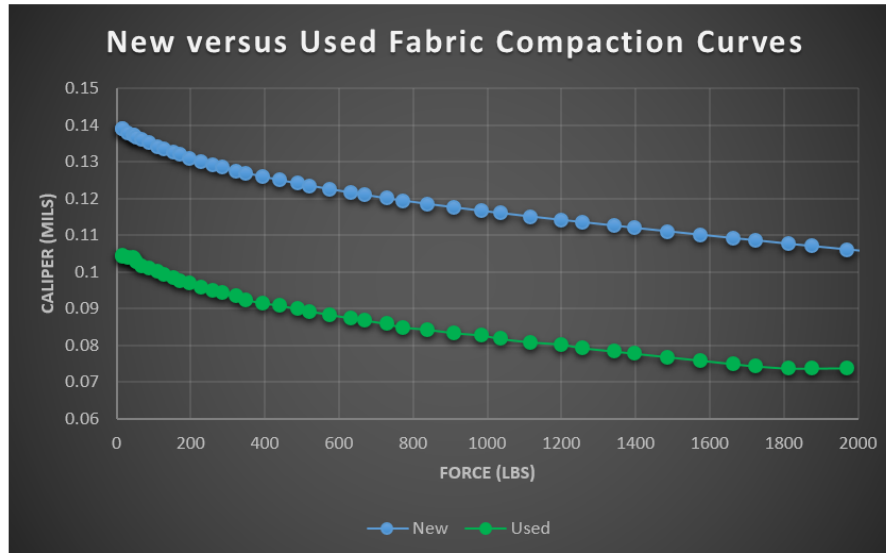
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- Caliper of Bases versus Load
 - New technology bases provide lower caliper
 - Lower caliper reduces time to saturate the pressing system
- Felts made with same yarn diameters and similar weights
 - New technology bases felts provide lower initial caliper
 - Lower initial void volume

Impact of Felt Calipers

Figure 6. Impact of caliper under load – New vs Used Fabric



	Caliper	mm caliper	GSM	Void Volume
New	0.14	3.556	1800	56
New	0.105	2.667	1800	41
Used	0.105	2.667	1620	46
Used	0.073	1.8542	1620	23

- Caliper of felts versus Load
 - New Weight: 1800 gsm
 - Used Weight: 1620 gsm
 - Used felt under load will lose 59 percent of effective void volume
- Loss of void volume must be taken into consideration by building a nip system, rolls and felts, with appropriate excess void volume

Summary

- One percent sheet solids can provide, up to, a 5 percent reduction in energy
- Faster press system saturation can lead to more efficient press dewatering
- Press rolls need to be optimized for proper excess void volume and hardness
- Press felts need to saturate easily and maintain enough void volume at the end of life

THANK YOU