A systems approach to felt conditioning

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ABSTRACT

Felt conditioning is a very important part of the total papermaking process, but it is often misunderstood. There are many significant felt conditioning variables, including felt design, machine speed, vacuum level, vacuum factor, dwell time, uhle box and cover design, showering, vacuum system layout, and chemical cleaning. Often the cause/effect relationship of these variables is not obvious. This results in inadequate sheet dewatering in the press, crushing and other quality defects, short felt life, and sheet moisture variations. This paper reviews the key factors in felt conditioning and presents actual case studies where measurable results have been achieved.

Application:

This paper would be useful in troubleshooting and optimizing press felt conditioning, resulting in improved felt performance.

THE EXTENT OF FELT CONDITIONING varies by grade, machine speed, furnish (recycle or virgin fiber), paper machine age, and, obviously, papermaker knowledge and experience. Sometimes, a little knowledge is dangerous, and the frequently misused solution to a problem, "more is better," quite often is applied. Many mills have experienced felt conditioning problems and make changes in the process, such as more vacuum, more slot width, more showering, and even more uhle boxes. Sometimes the process is improved, but frequently there are negative results. There have been several press rebuilds which occurred partly due to poor application or lack of felt cleaning equipment. A discussion of the above items and variables, as well as some actual case studies, should lead to a better understanding of the entire felt conditioning process.

FELT MOISTURE RATIO VS. PERCENT MOISTURE

Typically, felt moisture is surveyed with a "Scan-Pro," a device which measures the amount of water in the felt as g/m^2. This raw data is then reported in two ways: moisture ratio and percent moisture. A problem exists here because these values are often used synonymously, and they are not the same. Two simple equations define these terms.

Moisture ratio = Grams of water/Grams of felt (1)

% moisture = Grams of water x 100/Grams of water + Grams of felt (2)

Since both properties are unitless, one may not be aware when an error is made. For example, a felt with a moisture ratio of 0.40 has the same amount of water as the same felt with 28% moisture. Often the felt moisture studies are quickly looked at, and the papermaker will see 28 is less than 40 and not realize the felt moisture is equal.

A worse situation exists when a felt is reported to be at, say, 32% moisture, and it is believed to be drier than one with a moisture ratio of 0.38. It is not. Typically, these two values will not be used in the same moisture study, but both will be used in studies reported by different felt vendors.

Furthermore, regarding moisture studies, it is important to obtain moisture values before and after the uhle boxes. Even if a CD profile is not possible due to press geometry, an MD measurement should be taken. A moisture level measured in a felt only before a uhle box is about as practical as trying to estimate reel moisture based on a sheet moisture measurement in the middle of the dryer section.

UHLE BOX SLOT WIDTH VS. DWELL TIME

Uhle boxes, or felt boxes and felt tubes, as they also are called, are the devices which remove water and contaminants from a wet or press felt. They appear simple and have no moving parts. However, a lot of good engineering goes into the correct design and application of uhle boxes.

The first two variables in selecting a uhle box are slot width and felt width. Slot width is proportional to machine speed and is responsible for dwell time over the vacuum zone. Dwell time is the time, usually expressed in milliseconds, that the felt is exposed to vacuum.

A revision of TAPPI TIS 014-55, "Air Flow Requirements for Conditioning Press Felt at Suction Pipes," has been underway for the last three or four years. The revised Technical Information Sheet, TIS 0404-27, was published in early 1996. Extensive research was conducted to predict moisture levels in modern press fabrics. One of the most important variables was found to be dwell time.

Felt/machine speed, m/min (ft/min)	Total slot width, mm (in.)
Below 300 (980)	12 (0.5)
300-450 (100-1500)	15 (0.6)
450-600 (1500-2000)	20 (0.8)
600-750 (2000-2500)	25 (1.0)
750-900 (2500-3000)	30 (1.2)
900-1050 (3000-3500)	35 (1.4)
1050-1400 (3500-4500)	40 (1.6)
Above 1400 (4500)	46-50 (1.8-2.0)

I. Guide for determining slot width

Uhle box capacity, m^3/min (ft^{3}min)	Uhle box diameter, mm (in.)
20 (700)	150 (6)
34 (1200)	200 (8)
54 (1900)	250 (10)
79 (2800)	300 (12)
110 (4000)	350 (14)
160 (5600)	400 (16)
230 (8000)	450 (18)
290 (10000)	500 (20)

II. Recommended uhle box diameters

A dwell time of 2–4 milliseconds yielded successful water removal *(1, 2)*. The formula for determining slot width is:

Slot width (mm) = Dwell (milliseconds) x Machine speed (m/min)/60(3)

Slot (in.) = Dwell time (s) x Machine speed (ft/min)/5 (4)

This formula is used to determine the recommended total slot width on each uhle box, not each slot. For example, a calculated slot width of 25 mm (1 in.) would typically be applied using a double slotted uhle box with two 12.5 mm (0.5 in.) slots. Rearranging the equation to calculate dwell time on an existing uhle box:

Dwell time (milliseconds) = Slot width (mm) x60/Machine speed (m/min) (5)

Dwell time (s) = Slot width (in.) x 5/Machine speed (ft/min) (6)

A dwell time significantly less than 2 milliseconds can lead to incomplete water removal by the uhle box. Conversely, a dwell time over 4 milliseconds does not increase water removal enough to justify additional vacuum capacity.

Slot widths vary typically between 12 and 25 mm (0.5 and 1 in.). A slot less than 12 mm could plug or bridge over. A slot width of 12 mm is usually suitable for machine speeds up to 1000 ft/min. A slot greater than 25 mm could cause excessive felt wear. Usually, after the desired total slot width on a uhle box exceeds 25 mm, a double slotted box is used.

The research involved in the new Technical Information Sheet showed there was no meaningful difference in felt moisture exiting the uhle box due to single or double slots of the same total width. A guide for determining the total slot width, per uhle box, based on a dwell time of 2 milliseconds, is shown in **Table I**.

UHLE BOX DESIGN AND VACUUM FACTORS

The next item after determining slot width and resulting area based on felt width is to apply the vacuum factor. TAPPI TIS 0502-01 recommends a minimum of 660 m^3/min/m^2 (15 ft^3/min/in.^{2}) open slot area *(3)*. Furthermore, it is stated that factors have ranged from 750 to 970 m^3/min/m^2 (17 to 22 ft^3/min/in.^{2}), especially on felts heavier than 1375 g/m^2 (4.5 oz) and long nip or shoe presses. The uhle box vacuum capacity is determined by the formula:

Vacuum capacity = slot area x vacuum factor (7)

Now that correct vacuum capacity has been determined, an often forgotten item is to properly size the uhle box diameter. On new or upgraded vacuum systems, much effort is spent to minimize vacuum losses within the vacuum system piping. However, uhle box diameters are usually ignored. Since uhle boxes are conveying vacuum capacity across the felt width while carrying liquids and solids, it makes sense to size them as is done with vacuum piping. Typically, 18–20 m/s (3500–4000 ft/min) are velocities used for vacuum piping with liquid water (prior to a separator), and 28–30 m/s (5500–6000 ft/min) are velocities for vacuum piping with relatively dry air (after a separator). Therefore, it is recommended to size uhle boxes using the wet air velocities. For high vacuum capacity flows, it is necessary to increase these velocities further because of size restrictions within the press. Recommended uhle box diameters for various capacities are shown in **Table II**.

The quantity and placement of uhle boxes is less of a science and more of an applications experience. Theoretically, one uhle box per felt is adequate, assuming correct dwell time and vacuum factor. However, two uhle boxes may be used on felts carrying more water, where sheet fillers are used, on the fastest machines, and for assuring good moisture profile on high quality, lightweight sheets. Machines operating below 610 m/min (2000 ft/min) usually do not require two uhle boxes per felt. Also, on the driest felt positions, only one uhle box is needed (3rd or 4th presses).

Placement of uhle boxes can be from horizontal to vertical felt runs. There have even been specially constructed uhle boxes placed upside down in difficult press sections. Care should be given to allow enough space to accommodate oscillating needle showers, chemical showers, and lube showers ahead of the uhle box. Only a lube shower is required ahead of the second of two uhle boxes.

Uhle box cover or wear strip material and configuration also vary widely. High molecular weight polyethylene is most common, but it has many different formulations. These differences affect life and cost and should be evaluated. Ceramic cover material has a relatively high initial cost, but it can be justified over time.

Ceramic wear strip/cover material is successfully used on uhle boxes. Its advantage is long life, especially on higher speed machines. Be aware that not all uhle boxes will accommodate ceramics due to structural and space limitations or lack of rigidity. The price of ceramic is initially high and ranges from five to ten times the price of polyethylene. Additionally, there are different grades of ceramic with corresponding differences in prices. The lowest cost ceramic is aluminum oxide; silicon nitride is the most expensive. Another advantage to using ceramics is reduced or no pitch buildup on the ceramic strips. This buildup varies with mill and region.

The last major topic on uhle box design is the design of the “slot” opening. Traditionally, a straight slot, multiple slots, or a herringbone pattern were the only choices available. With the development of seamed felts, other designs have evolved to minimize seam wear. Some of the new slot configurations have also led to reduced felt wear in general and may be worth consideration.

SHOWERING

Felt showering has experienced extensive changes over the last ten years. Some changes are due to the need for cleaning modern press felts. Other new developments are due to new equipment technology. Developments of new designs and materials for press felts have resulted from the requirements of long nip and heavily loaded presses. These major innovations in pressing occurred in the early 1980s, leading to significant innovations in felt design and construction. These innovations spread through most paper and board grades. Cleaning these modern felts requires modern showering techniques. Continuous, not intermittent, showering with a combination of low pressure fan and lube showers plus high pressure, oscillating needle showers must be applied properly.

A properly designed felt conditioning system will allow continuous use of low- and high-pressure showers *(4)*. A common belief is that a uhle box only extracts water that was absorbed by the felt. Actually, in a well designed system, only one-third of the water removed by the uhle box comes from the sheet. The other two-thirds of this water is from low and high pressure showers. This point leads up to the fact that contaminants in a felt cannot be removed only by applying vacuum. Water is required to loosen and help convey debris from the felt.

Fan showers are for evenly wetting the entire width of the felt. They operate at relatively low pressures of 3–4 bar (40–60 psig). Most often these are placed directly ahead of uhle boxes as lubrication showers. The shower must be designed to provide complete and even coverage of the felt. Some mills are oscillating these showers to minimize effects of plugged or poorly operating nozzles. It is important to have all fan nozzles spraying uniformly. This also leads to the use of showers with internal brushes to aid in cleaning the nozzles on the run.

High-pressure needle showers produce a high energy spray which is concentrated on a very small area. However, only a thin strip of clothing is cleaned as it moves past the nozzle. It is not practical to have enough needle nozzles on the shower pipe to completely cover the felt. This would also be prohibitive due to pumping costs of high-pressure water. The solution is to move the shower axially, back and forth across the felt. This movement should be at a constant rate with little or no dwell at the end of the stroke.

The mechanisms used to produce the shower movement have included pneumatic and hydraulic cylinders, gear motors with crank-arms and, more recently, self-contained, electromechanical shower oscillators. The apparently simple, cylinder-driven and crank-arm designs were limited as they did not provide the uniform stroke rate and instant directional change for the shower. These oscillating showers provide a random cleaning of the felt and may completely bypass some areas. This non-uniform cleaning causes felt streaking and CD sheet moisture variations in the worst cases.

These self-contained, electromechanical shower oscillators were introduced in the early 1980s. They also had the feature of speed control. This new feature achieved complete coverage cleaning of the felt by moving the shower across the felt a distance equal to the width cleaned by a single nozzle, with each full revolution of the felt. This motion can be calculated by the equation:

$$S\,T/L = R \qquad (8)$$

where

KEYWORDS
Equations, equipment, felt conditioning, hydraulic equipment, moisture, moisture content, problem solving, showers.

S = felt speed in m/min (ft/min)
L = loop length of the clothing in m (ft)
T = nozzle cleaning width in mm (in.)
R = stroke rate in mm/min (in./min)

The stroke rate determined by this method is relatively much slower than that observed with previously used oscillators. The stroke rate could vary from less than 6 mm/min (0.25 in./min) for a long, wet felt on a slow cylinder machine to 100 or 150 mm/min (4 or 6 in./min) for a typical press felt on a high-speed newsprint machine. Many times the speed control for the electromechanical oscillator will be interlocked to paper machine speed controls so the machine speed for different grades can be tracked.

Shower stroke length is based on the shower nozzle spacing. Most nozzles for felt cleaning are placed on 150 mm (6 in.) centers. The recommended stroke length is two times the nozzle spacing, i.e., 300 mm (12 in.) stroke with nozzles on 150 mm (6 in.) centers. The reason for this relationship between stroke length and nozzle spacing is to provide 100% nozzle overlap in the event a nozzle is plugged. Since needle showers have relatively small nozzle orifices, typically 1–1.5 mm (0.040–0.060 in.) diameter, the use of clean, filtered water is important. Additionally, as with fan showers, internal brush mechanisms are also used with needle showers. In some very critical applications, a pipe-within-a-pipe configuration may be used to allow removal and maintenance of the shower and nozzles on the run.

Usual pressures for needle showers vary from 10 to 17 bar (150 to 250 psig). Higher pressures can damage the felt, and lower pressures do not provide adequate cleaning energy. Placement of these showers is also important. Cleaning modern press felts requires needle showers to be located on the sheet side of the felt. It is practically impossible to clean these multi-layer, heavy felts from the inside as was done only 10 or 15 years ago. The angle of the needle spray with respect to the felt will vary with felt construction, shower design, and papermaker experience. There are many opinions on this matter, so a new one will not be introduced here.

The final and most important point on shower placement is the proper distance from the shower to the felt. The best cleaning is obtained at distances between 75 and 150 mm (3 and 6 in.) from the felt. Much greater distances will allow the needle stream to break up and form small droplets, producing small energy pulsations on the felt and even damaging the felt.

VACUUM SYSTEM

The vacuum system consists of piping, separators, valves, separator removal pumps, seal/weir tanks, and the vacuum pumps. An excess of vacuum pumps will not replace a poorly designed system, undersized piping, or lack of separation equipment. This paper began with determining the vacuum capacity and the sizing and selection of uhle boxes. This is the logical order of events leading up to the system design and vacuum pump selection.

One of the most important points in the system design is to have separate vacuum sources for uhle boxes on separate felts. One vacuum pump per felt will not allow two or more felts of different porosities to affect each other. There is no problem with connecting two uhle boxes together on the same felt.

Next, the vacuum piping must be sized *(5)*. This is based on velocity, as was done with the uhle box sizing. As stated earlier, vacuum piping before a separator should be sized with a velocity of 18–20 m/s (3500–4000 ft/min). Piping after the separator can be sized for 28–30 m/s (5500–6000 ft/min). The piping runs should be horizontal or sloping downward before a separator, never uphill. After the separator, piping may be routed as needed to reach the vacuum pumps. Vacuum piping is most often stainless steel, but many systems have used carbon steel between the separators and vacuum pumps.

The vacuum separator is an important element of this system. With the constant showering, there are significant amounts of water, fiber, contaminants, and chemicals to remove before the vacuum pumps. Separator configuration may vary, but most designs employ a tangential inlet. Since the operation of a separator is primarily affected by the internal velocity, more efficient separation occurs at internal velocities around 2.5–4 m/s (500–750 ft/min). Most separators are constructed of stainless steel. The use of either one or two separators on a felt with two uhle boxes is acceptable. The choice is usually based on space availability. When two separators are used, the vacuum piping may be joined prior to the vacuum pump. However, the water outlet piping should never be joined. Each separator should have its own barometric seal line or water removal pump.

Water removal from the separators is also important. For most top felt uhle boxes, a barometric seal line can be used. Care must be exercised in routing this piping to minimize turns. Piping should be vertical when possible or never more than 45° from vertical. Typical velocities for sizing this piping are 1–2 m/s (4–6 ft/s). A minimum pipe diameter of 100 mm (4 in.) is recommended.

The other end of the seal line is at the seal tank. Most modern installations use multi-compartment seal tanks with one compartment per separator and calibrated weirs for flow measurement. This allows simple observation and assessment of felt water removal. The seal tank must be located at a sufficient elevation below the separator to overcome the effects of vacuum. This distance must be the vertical distance measured between the bottom of the separator and the liquid level of the seal tank. The direct conversion from kilopascals to meters of water is 3.4 kPa/m of water (1.0 in. Hg vacuum per 1.14 ft of water). Since this is a direct conversion, an additional 1 m (3 ft) should be added to allow for friction and as a safety factor. Also important is the volume of the seal tank. A simple rule is to size the seal tank volume for two times the volume of the seal line piping.

The final and also very important step is to select the vacuum pump. Heavier felt designs on today's machines require higher vacuum levels for dewatering. As discussed earlier, vacuum factors between 660 and 880 $m^3/min/m^2$ (15 and 20 $ft^3/min/in.^2$) will cause the uhle box vacuum level to reach 60 kPa (17 in. Hg) and often 68 kPa (20 in. Hg). Therefore, it is important to select a vacuum pump capable of a fairly constant capacity up to this maximum vacuum level. Additionally, it may be necessary to install a vacuum relief valve to limit maximum vacuum levels should the felt become excessively filled and compacted.

CHEMICAL CLEANING

Some felts require more than mechanical conditioning and cleaning with showers and uhle boxes. Some paper and board grades have furnishes and fillers that can adhere to the felt and may be difficult to remove unless chemical solvents or detergents are used. An optimum felt conditioning system utilizes both mechanical and chemical means to keep today's modern, synthetic felts open and functioning.

Contaminants often found in the analysis of old felts include soluble and insoluble material *(6)*. The shortest list is the insolubles such as fiber and fines, clay, talc, titanium dioxide, and silica. The mechanical action of showers and uhle boxes can remove most of these. The soluble materials come from the pulp mill furnish, recycled fiber supplies, and the broke system. They can be separated into three groups: acid, alkaline, and solvent solubles. These groups include aluminum hydroxide, calcium carbonate, wet- and dry-strength additives, lignin, starch, size, fatty acids, glue, latex, oil, grease, and wax.

Removing these and other contaminants with chemicals will require examination by the chemical supplier. Treating these conditions may be through batch, intermittent, or continuous introduction of chemicals. In most cases, the chemicals are applied to the felt through a stationary fan shower. Depending on the application, the shower may be located on the sheet or back side of the felt. For continuous or intermittent chemical cleaning, the shower is usually on the back side of the felt and positioned as close as possible to the point after which the sheet leaves the felt surface. This provides the most residence time to allow the chemicals to work before the uhle box extracts them. Again, the chemical supplier familiar with the mill's wet-end chemistry should be involved.

CASE STUDIES

Case 1

The pick-up felt on a 7.1 m (280 in.) linerboard machine was operating with two 300 mm (12 in.) diameter uhle boxes with herringbone covers and a vacuum factor of 480 $m^3/min/m^2$ (11 $ft^3/min/in.^2$). This low vacuum factor prevented the vacuum level from reaching beyond about 40 kPa (12 in. Hg). The vacuum pump was originally sized for two uhle boxes with double 16 mm (0.625 in.) slots and was capable of operating at up to 68 kPa (20 in. Hg). However, the slotted covers were replaced with herringbone covers when this position was changed to a seamed felt. The vacuum piping was properly sized and installed and included a vacuum separator. The separator flowed through a barometric seal line to a seal tank with a calibrated weir. Showering was good, with an electromechanical oscillator driving the needle shower. A lube shower was installed on each uhle box. The primary problem with the system was the excessive open area of the herringbone covers. In addition, the uhle boxes were undersized.

This system was improved with the replacement of the uhle boxes with new 350 mm (14 in.) diameter units. Uhle boxes 400 mm (16 in.) in diameter were recommended, but 350 mm (14 in.) units were the maximum size that would fit. More importantly, the covers were designed to have about half the open area of the previous herringbone covers. This yielded a vacuum factor of 880 $m^3/min/m^2$ (20 $ft^3/min/in.^2$). The notable item in this study was that there were no changes to the system other than new, larger uhle boxes with covers of less open area.

Results were significant and immediate. Vacuum level at the uhle boxes started at 34 kPa (10 in. Hg) on new felts and was at 50 kPa (15 in. Hg) within a week, due to initial compaction. Water removal increased by about 380 L/min (100 gal/min), as measured over the seal tank weir. The moisture ratio of this pickup felt dropped to 0.41, where previously it was 0.55 to 0.60. The measurably drier felt absorbed more water from the sheet and increased sheet dryness from the press section.

Steam pressure was reduced to the dryer at the same production rate.

Case 2

Another linerboard machine, in this case a 100% recycled, 4.6 m (180 in.) wide machine, was converted from a conventional, two-bottom felt press to a tandem bottom felt. The conversion was done to improve runnability and avoid a major press rebuild. This conversion led to a study of the existing felt conditioning system. The system was inadequate, with limited showering capability, undersized uhle boxes and low vacuum capacity. Vacuum factors were below 440 $m^3/min/m^2$ (10 $ft^3/min/in.^2$). All uhle boxes were connected on a common vacuum header.

The entire felt conditioning system was replaced, including vacuum pumps, separators, uhle boxes, and showers. The system was designed to allow separate vacuum sources for uhle boxes on each felt. New vacuum factors for the system were 790 $m^3/min/m^2$ (18 $ft^3/min/in.^2$).

Within 36 h after startup, production rates increased by 31%.

Case 3

A 5.6 m (220 in.) coated board machine was operating with poor felt life, 28–30 days, and sheet defects caused by high felt moisture. Felt showering had to be intermittent because the felts were already too wet. The felt conditioning system was studied, and several problems were identified. These included a common vacuum header for all uhle boxes, undersized uhle boxes, an excessive slot open area resulting in a vacuum factor of less than 220 $m^3/min/m^2$ (5 $ft^3/min/in.^2$), two uhle boxes per felt, no vacuum separators, inadequate showering, and undersized vacuum piping. However, the vacuum pumps were in good condition and were the correct size. They would be reused.

The uhle boxes were replaced with just one per felt and slotted covers yielding a vacuum factor of 660 $m^3/min/m^2$ (15 $ft^3/min/in.^2$). Vacuum separators with low NPSH removal pumps were installed, undersized vacuum piping was replaced, and felt showers were replaced with complete coverage designs. Again, the vacuum pumps were not changed.

Two new felts were installed, and immediate results were observed shortly after startup. Machine speed increased by 15 m/min (50 ft/min) with continuous showering, and many sheet defects disappeared. Both felts were cut off after 40 days and were determined to still have usable life. Felt life is now 45–50 days.

CONCLUSION

A little theory and common sense applied to most felt conditioning systems can produce significant results. Often these are not expensive solutions, and payback is fast. Gathering and interpreting data correctly is the key to problem identification. The solutions are relatively easy. **TJ**

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