Techniques for nip impressions

**Scope**

Paper machine technology has resulted in faster running paper machines with ever increasing operating pressures in the press and other sections of the paper machine. It is now more important than ever that the operating pressure between two or more rolls be evenly distributed across the face of the nipped rolls to insure product quality and roll cover integrity. One way to ascertain if a uniform pressure distribution is being applied is to take nip impressions. This Technical Information Paper reviews the need for nip impressions, the various media available to perform the work and general instructions for taking the impressions. In addition, measurement analysis is addressed and a crown correction equation based on nip impression measurements is discussed.

**Definitions**

A nip impression is the footprint of two mating rolls taken under controlled conditions. To be of maximum use, it should be continuous across the face of the rolls forming the nip. It should also be made with materials that are capable of showing a reasonably sharp transition between the loaded and unloaded areas on the paper, film, foil, or electronic nip profile sensor being used to obtain the impression. There are four major commercially available products used to acquire nip impressions.

1. A traditional method uses paper and carbon paper which are used together so that the carbon paper produces a copy of the pressurized area on the plain white paper. It must be used in a dry environment or protected with a waterproof envelope of some type if in the environment is wet.
2. Embossed metallic foil (usually aluminum) is another used medium. It has the advantage of being able to be used under wet and very hot conditions. It is somewhat more difficult to measure than the carbon paper and does not store as well. It has a tendency to wrinkle, which makes reading the results difficult.
3. The third material consists of two plastic films, one of which is coated with micro capsules with graduated resistance to rupture under pressure. The other film is coated with a material that reacts with the contents of the ruptured micro capsules to generate a color of varying intensity. This material can be used statically as is done with carbon paper and foil or it can be rolled through a nip between slowly rotating rolls. To take full advantage of the potential of this method, it is necessary to use an instrument capable of measuring color intensity differences. A distinct advantage of this method is that it can be used to take both slow rolling and static nip impressions with the felt(s) in place.
4. The fourth medium is electronic nip impression sensors, which provide nip width readings, pressure readings, or both. The sensors are placed in the nip as with the previous methods, but are connected to a computer for real-time output display. The sensors are usually encapsulated in a film, so they may be used in wet conditions. The sensors, however, are limited to temperatures less than 350 F. The distinct advantage of this method is the ability to take multiple nip impressions using numerous load profiles without changing the sensor medium in the nip.
Safety precautions

Anytime people are working with heated or steam pressurized rolls, extreme care is required. Whenever working around roll nips, extreme care must be observed. Lock out/tag out rules must be followed when applicable while completing nip impressions. Any drive or loading control jumpers required must be returned to operational state once measurements are completed. Use proper fall arrest attire or equipment as required while completing measurements.

Background

There are many variables at work during the operation of a paper machine. These variables make it difficult, if not impossible, to judge the condition of an individual nip simply from entering or exiting sheet characteristics. This means that the moisture profile of the sheet or a felt in a press section does not necessarily give a good indication of the uniformity of the nip pressure. Why then should the papermaker be concerned about the nip if the product is within specification? Intuitively, it would seem that if all the components of a system were operating at maximum efficiency, the system as a whole would also be operating at maximum efficiency. In the case of a paper machine, this should translate into higher speed, less steam consumption, more uniform coat and size distribution, longer life of roll covers and felts, and an overall increase in machine efficiency. The critical roll covers come in many compositions such as polymeric, composite, and filled rubber.

A nip is formed when two rolls are loaded against one another. The load is usually expressed in pounds per linear inch (PLI) (kN/m). Rolls are normally crowned, either positively or negatively, to compensate for core bending and distortion under applied loads. If the crown is not correct, the load will vary across the roll face. Some areas will have higher loads while adjacent areas may have lower loads. The running characteristics of covers are highly load dependent. A non-inclusive list of cover properties dependent on applied load (PLI) (kN/m) include heat buildup, speed differential with the mating roll, wear, and surface deterioration. All of these factors would be uniform if the nip were equal across the roll face.

Uneven heat buildup during operation can result in thermal crowning which can in turn distort the specified crown. In severe cases, heat generation may result in cover separation from the metal roll core. A melt down starting below the surface and above the metal may be the result with some cover materials. Internal water cooling may or may not alleviate this condition.

Uneven loading of nipped rolls can result in a speed variation between rolls, with and without different cover hardnesses. Varying the load (PLI) (kN/m) across the roll face also results in varying speed differentials. The result of these variations in speed differential is accelerated cover wear and more frequent grinding to return the surface to its desired operating condition.

Rubber can stretch and return to its original length on a recurring basis without deterioration. This property remains true as long as the amount of stretch is below what is termed its critical elongation. If that critical elongation is exceeded, cracking will occur quickly. Since rubber is incompressible, it must stretch when going through the nip. The amount of stretch depends on the line load (PLI) (kN/m). In the case of the harder cover materials that are used today, crack prevention can be improved by ensuring a uniform nip load exists across the entire roll face.

In addition to the effect on roll covers, non-uniform cross machine direction pressure distribution in the nip will have varying degrees of effect on paper properties and press felt life. This effect is more pronounced if the rolls involved are made from hard material i.e., granite, ceramic, metal, and even bone hard polymeric covers.

The following information should be shown on or attached to every nip impression:

1. Centerline diameter to the closest 1/64 in. (0.4 mm) on both rolls.
2. Machine number and nip identification i.e., 1st press, size press, etc.
4. Identification of tending and drive sides of the impression.
5. Date and time of day.
6. Loading pressure used. If different on tending and drive sides, so specify. If gauge pressure\(^1\) is used, also state equivalent (PLI) (kN/m).

\(^1\) Conversion of gauge PSI (bar) to (PLI) (kN/m) is a detailed calculation (requiring press loading system data) that has already been done by the original supplier of the equipment. This is commonly given to the mill (as a conversion chart) at press installation and should be kept on file.
Indicate if the rolls were newly ground or old rolls (indicate installation date).

Design crown for both rolls.

Other items of interest such as whether the impression taken on hot rolls and the direction of roll rotation.

Taking the nip impression

The following instructions are general in nature since there are a variety of press configurations and roll types installed, and it would not be possible to provide comprehensive information to cover all cases. It is recommended that in those cases, where there are multiple nips or controlled crown rolls, the press or calender stack supplier be contacted to get detailed instructions on taking nip impressions on its equipment.

Rolls should be newly ground before taking nip impressions that will be used to establish crown changes. A roll is crowned to compensate for deflection due to roll weight, vacuum, clothing tension, and normal running nip load. A nip impression taken on worn rolls will not produce an accurate indication of the deflection but will show the loading characteristics under the current conditions of operation.

Rolls should be rotated for at least an hour before taking the impression to eliminate any effects of core sag.

Observe all safety precautions since the nip points are considered areas of high risk.

The nip impression medium will be referred to as “nip paper” although it may be any of the four media referred to above. While the general instructions that follow are guidelines for taking nip impressions, the suppliers of the various nip impression media do provide detailed instructions for use of their products.

In multiple/cluster roll press sections, adjacent rolls should also be loaded to provide the correct operational affects on the nip being measured. For instance in a tri-nip type press arrangement, all three nips should be loaded.

Static nip impressions

1. Pull out a length of nip paper long enough to overhang both ends of the roll.
2. Tape the paper to one of the rolls, being sure that the nip paper is straight along the roll width. In the case of using a two-part system, make certain the two layers are put together correctly.
3. Rotate the roll, if necessary, so that the nip paper will be in the center of the nip when the nip is closed.
4. Close the nip using the minimum amount of pressure to bring the rolls together. Load both sides at the same time. Remember, all nip impression media measure the maximum pressure they have been subjected to. If a non-uniform rate of loading (one end loading before the other) occurs, the nip impression will reflect this and will not give a realistic representation of the pressure distribution in the nip (this is not an issue with electronic nip impressions).
5. Gradually increase the pressure on both ends at the same time until the desired loading has been reached.
6. Hold for one minute.
7. Gradually decrease the pressure uniformly from both ends until the rolls disengage.
8. Remove the nip impression paper and examine the impression obtained to be sure it appears representative of the entire nip (not necessary for electronic nip impressions).
9. If another nip impression is to be taken, rotate both rolls so the new nip impression will not be taken in the same place as the previous one(s) were.

Slow rolling nip impressions

Slow rolling nip impressions are usually taken by feeding micro-encapsulated films through the nip at low speeds. One should mark the tending end of the film before the test, since there is a chance that the film will not be in the same orientation after the test. One may also crease the film (or use a pen or fingernail to scribe) at the ends of the felts or rolls to mark the edges. Before the test, the film is usually taped to a roll or press fabric. Avoid using duct tape, since it is difficult to remove. Also, it is best to tape the film outside the loaded face at the end of the roll, where the tape will not be loaded. A thick application of tape across the film can negatively influence the readings. After the measuring medium is installed on the roll, the machine is started at its slowest speed and then stopped after the film has passed through the nip so the film may be retrieved. The film should be retrieved gently, since it will record kinks and finger marks, especially on the lower pressure range films. The films are generally removed from the protective envelopes and rolled up while awaiting interpretation.
Electronic nip impressions

Electronic nip impressions are taken using the same steps as non-electronic static nip impressions, but there are a few differences worth noting. Since these sensing systems provide real-time feedback, one expects to make real-time adjustments. The user should record a sequence of press loads starting at a level below the normal operating level and extending to a load about 10% above the normal operating level, if this higher load may be achieved safely. Certainly, all the typical operating loads and biases should be tested. If the loading is to be reduced on one or both ends, the press should be opened, since covers, press fabrics, and sensors all have some level of hysteresis. Then reload to the desired level. Multiple nip impressions provide a record of the load levels required for a flat nip and also of the press sensitivity to variations of these settings. Non-uniform rates of loading, end to end, are not an issue for electronic nip profiles.

Dynamic nip impressions

New technology has been developed that embeds sensors into the depth of the roll cover and provides a dynamic real time nip impression during operation. These systems provide both pressure and nip width profile measurements. This method of taking nip impressions eliminates the errors associated with static nip impressions that do not consider variables such as operating temperature, cover dynamic modulus, vibration, vacuum, clothing tension, and other static concerns identified earlier. The pressure and nip width distribution are plotted in real time and stored so they can be accessed at any given moment during machine operation.

Suction rolls

Suction rolls present a special problem because part of the core bending or distortion load is the result of the application of vacuum. This can be addressed by sealing off the section box area with plastic and applying an amount of vacuum equal to that normally run in the roll. The estimated linear load created by the applied vacuum can be found from the following equation.

\[
\text{Vacuum PLI kN/m} = 0.4912 \times W \times V \times F
\]

where

\[W\] = the machine direction width, in inches (millimeters), of the vacuum box
\[V\] = the vacuum level, in inches (millimeters), of mercury
\[F\] = box seal efficiency factor (\(F = 0.9\) for most suction rolls)

Yankee pressure rolls

Paper machines with Yankee cylinders present special problems when taking nip impressions. The temperature is too high for using carbon paper. A rubber covered roll held against a hot Yankee cylinder during the taking of a nip impression would damage the cover. The best methods are the micro-encapsulated plastic film or a high temperature electronic nip profile. The electronic systems are capable of being used on surfaces up to 350°F. If high temperature electronic sensor strips are not available, an envelope of some type must be used to protect the film from moisture and heat. Heavy paper or plastic have been successfully used as the envelope but these protective envelopes will increase the measured nip width by more than an inch. In this case, a slow rolling nip impression would probably be more accurate than a static impression. The following conditions should exist to obtain a meaningful nip impression:

1. The pressure roll should be newly ground and the felt should be no more than ten days old.
2. The Yankee cylinder should be hot and contain the normal running steam pressure.
3. If a second pressure roll is normally used, it should be loaded to its operating pressure.
4. If possible, the pressure roll should have run approximately 24 hours before the test.
5. The pressure roll to be checked should be loaded to the value for which it is crowned.
6. Immediately after ceasing to make paper, reduce the machine speed to crawl and pass the film through the nip.

7. Interpretation of the results is done by using instrumentation to measure the color intensity which relates to the nip PSI (kN/m).

Dynamic nip impression systems with embedded sensors are particularly beneficial for the nip between Yankee dryers and pressure rolls. These systems take measurements with the Yankee steam pressure at operating levels, with a relatively cool sheet on the Yankee, and with the cover at temperature due to the hysteresis of the cover. All of these variables affect the compound crowns required for Yankee dryers and static nip impression do not adequately consider them.

Interpreting the nip impression

Usually the first interpretation of the nip width is completed immediately following the removal of the nip paper from the roll surface. Take the paper and put the two ends together so that the impression of each end can be looked at to see if there is a variation. This will also establish the centerline of the nip impression. Visually compare the widths of the impression from the ends to the centerline. This test is to see if the nip width is symmetrical. If it is, then proceed to the next step. If it is not, try to determine why it is not and make whatever changes are necessary to make it approach symmetry. Take nip impressions until symmetry is attained.

If the only object of taking the impression is to establish if crown correction is required, the only measurements needed are the nip width at the centerline and at each end of the roll. The nip widths at each end are measured at crown station 0. Once these measurements have been made, the amount of total crown correction can be calculated from the equation:

\[
C = \frac{(N_2^2 - N_1^2)(D_1 + D_2)}{2D_1D_2}
\]

or if rolls have equal diameters

\[
C = \frac{N_2^2 - N_1^2}{D}
\]

NOTE 1: If \(C\) is minus, then the nip is over crowned

As an example, let us assume that we have two 30-in. (762-mm) diameter rolls and we find that the nip widths are 0.9 in. (22.9 mm) on the ends and 0.7 in. (17.8 mm) at the center under the loading at which we desire to run the rolls. Then by our formula:

\[
N_1 = 0.7 \text{ in. (17.8 mm)}
\]
\[
N_2 = 0.9 \text{ in. (22.9 mm)}
\]
\[
D = 30 \text{ in. (762 mm)}
\]

\[
C = \frac{(0.9)^2 - (0.7)^2}{30} = \frac{0.81 - 0.49}{30} = \frac{0.32}{30} = 0.011 \text{ in. (2.8 mm)}
\]
There are many techniques for measuring the width of the nip. Even though carbon paper has been carefully chosen to give as sharp an edge as possible, it is still slightly fuzzy. The technique that has given the best and most reproducible results is to first mark off the nip impression in 21 crown station intervals. Then using a straight edge and a pencil with a very sharp point, draw a line about 4 - 6 in. (101.6 - 152.4 mm) long at the impression edge at each side of the impression and centered at the crown station. Using a scale graduated in 0.02 in. (0.51 mm) increments, measure the width of the nip as accurately as possible. These measurements are dependent to some extent on the person who takes them. They are not completely objective. It is therefore best for the same person to draw the lines and take the measurements.

Nip width impressions can be used to determine not only the amount of crown necessary for a given nip load but also the shape of the crown. The usual crown shape is a 70 degree cosine curve, but the use of 90 degree cosine curves is not uncommon. Higher degree cosine curves are used to correct problems which appear at the quarter points. Size presses can be particularly prone to quarter point problems. Compound crowns are used where relief from overloading of the roll ends is required. For example, consider two nip impressions having the same center and end readings but different shapes, as shown in Figs. 1 and 2 (I). The profile shown in Fig. 1 indicates an undercrowned condition. An increased crown would lead to a flatter nip. The profile shown in Fig. 2 shows the need for edge relief; the existing simple crown amount is probably acceptable. A compound crown or edge tapers are required to correct these conditions. The calculations resulting in the accurate determination of these crown shapes are complex and require the use of sophisticated computer programs which are regarded as proprietary by machinery builders and roll cover suppliers. If problems are not solved by the simple changing of the amount of crown indicated by the equation using nip widths and roll diameters, it is recommended that you seek assistance from your roll cover supplier who can suggest a solution based on the nip impression that has been taken.

Most of the above information has stipulated that the nip width impression be taken from newly ground roll covers. The nip width impression can also be used for trouble-shooting problems with worn rolls. Many mills routinely take nip impression on rolls every time they have an opportunity. This gives a picture of what is going on under actual operating conditions and when coupled without crown measurements can often lead to changes in crowns or other operating conditions. For a visual display of the nip or crown profile, plot the 21 crown station values on a graph. This helps create a more comprehensive way of seeing what is occurring in the nip. Ongoing records of these plots may identify a trend that would not be easily found with just a list of numbers. Keeping accurate and complete records for troublesome nips can assist greatly in determining corrective actions.

Thermal crowning due to operating conditions can be a problem. It is true that water cooling minimizes thermal crowning, but it can occur even when water cooling is used. One way to establish that thermal crowning is taking place is to take a nip width impression not only on newly ground rolls when they are reinstalled, but also after rolls have reached running equilibrium temperature. This technique has proven especially valuable in size presses and calender stacks.

Although both static and dynamic techniques are used in obtaining nip impressions in supercalenders, it should be noted that fully loading the calender under static conditions may possibly damage filled rolls or composite covers. Dynamic nip impressions for verification of CD nip uniformity are made with pressure sensitive type papers.

It should be noted that a nip width measured under static conditions is wider than the dynamic nip under the same conditions.
Fig. 2. Nip width profile showing need for end relief

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Literature cited


Additional information

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