ON THE USE AND CARE OF SUPERCALENDER ROLLS

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Special monitoring tools can be used to extend the life of a supercalender cover and to improve overall calender stack performance.

Supercalender rolls are used to improve the properties and increase the value of paper. Specifically, paper properties such as caliper or bulk uniformity, smoothness, and gloss are improved by this process. However, the supercalendering process is costly and is in need of improvements.

In 1974, Bentley, Peel, and Kitching *(1)* wrote, "The two most desirable improvements in the supercalendering process that industry would like to achieve are probably the extension of the life of a filled roll and the ability to obtain a similar finish on-machine. These may come about only if the calendering conditions or the filled roll materials, or both, are changed from those presently used to others whereby the undesirable effects of high loads and temperatures on the roll are greatly reduced. The two principal effects are the marking of the surface . . . and the disintegration of the roll material below the surface . . ."

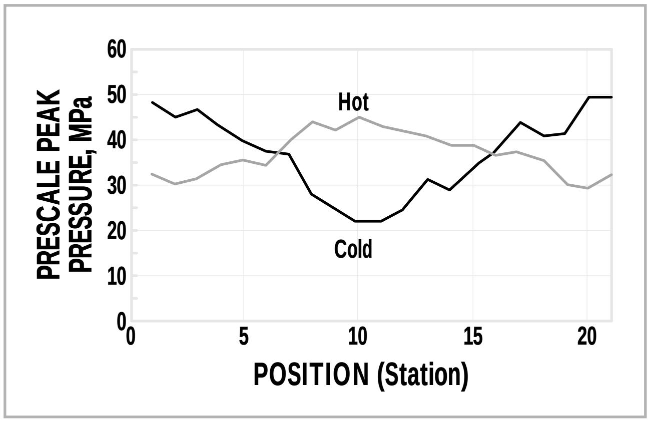
Toward making these improvements, the industry has developed synthetic roll covers that have extended wear and mark resistance compared to those of traditional filled rolls. Also, on-line systems are becoming a reality with soft-nip calendering, and new-generation systems are being tested for on-line supercalendering. However, the evolution of the calendering process has also brought about more rigorous application conditions; higher temperatures and pressures are applied together with greater speeds. Cover marking and failure continue to be obstacles to optimum calender efficiency today.

Many papers have been written on the topic of improved roll and cover materials and on improved calendering equipment *(2–6).* The present paper will focus on maintaining the process conditions a little closer to the ideal without substantial capital investment. In other words, "How can I optimize the performance of my existing equipment?" This presentation lists some of the tools available to calender operators to troubleshoot the stack and extend cover life and discusses examples of these tools in action.

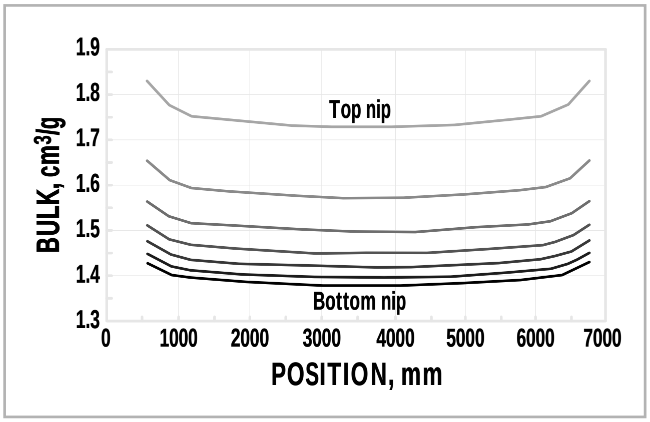
AVAILABLE TOOLS

The papermaker has a wealth of process variables under his/her control, but rarely does a single variable stand alone. For example, temperature changes across the roll may indicate a loading problem. As one pushes the limits of the process, one must be particularly careful that the environment is not too severe for the roll materials. This care may reduce operating expenses through the extension of the roll regrind interval and roll life. Here we list a few of the tools briefly; their application will be discussed in more depth later.

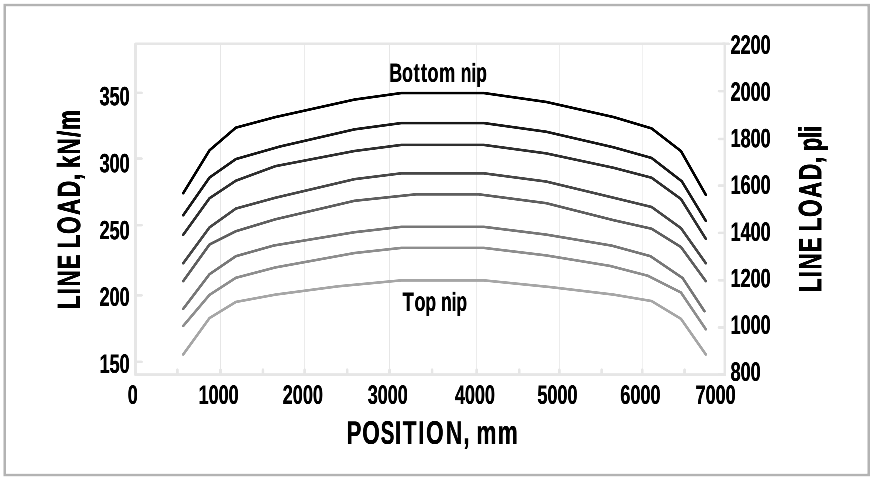
- Temperature profiles across a roll may indicate loading problems, sheet temperature variations, and inadequate roll shape. Small temperature guns are relatively inexpensive and are easy and convenient to use.
- Nip impressions indicate the pressure variations across the machine and provide insight concerning the resulting bulk distributions.
- Roll profile data can help explain loading and the bulk variations.
- Maintenance records should contain details of where and when wads, marks, and breaks occurred (at which nips and at what cross-machine position) along with the installation dates and run times of the rolls. This information is of great use for baseline reference and failure analysis.



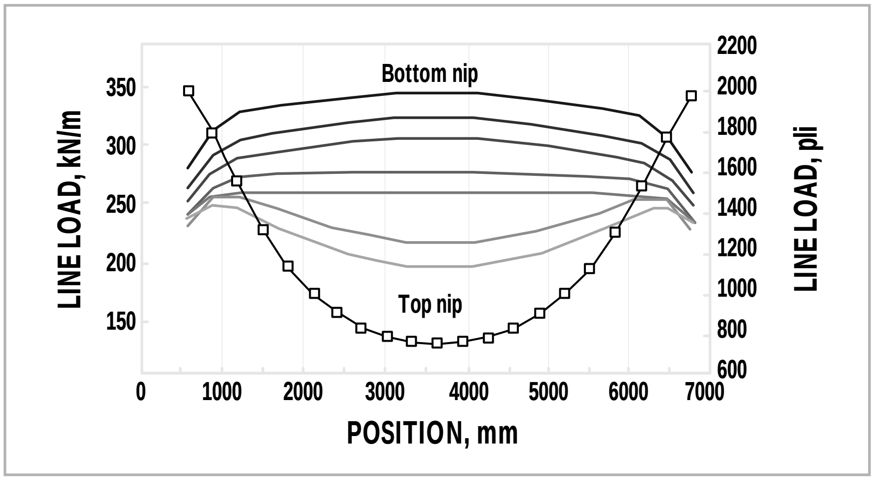
1. Effects of temperature on nip impressions



3. Cool-end bulk progression



2. Cool-end loading profile



4. Undercrowned Queen roll

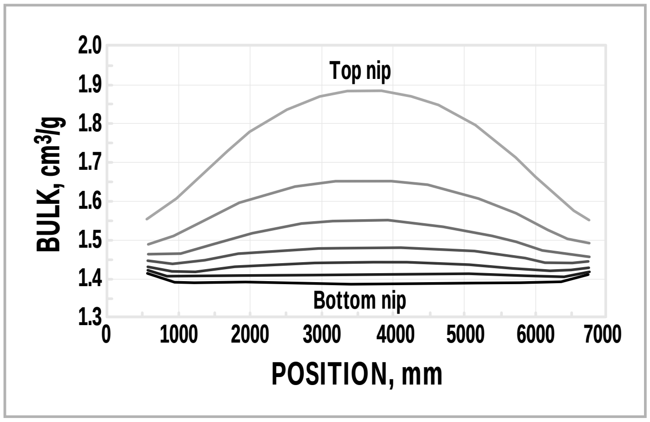
Proper use of these tools can increase the life of the roll covers and improve the mechanical conditions of the reel. The following examples illustrate the use of these tools and the results.

EXAMPLES

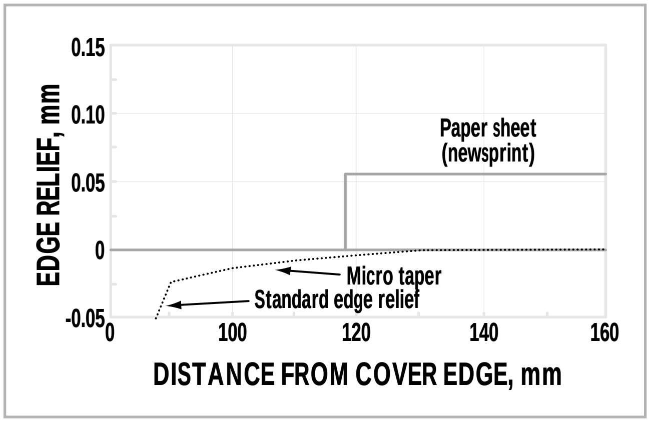
In this section, we present examples of process conditions and discuss methods to improve the sheet properties and cover life. These examples have been adapted from actual mill cases and from the literature.

Wrong crown

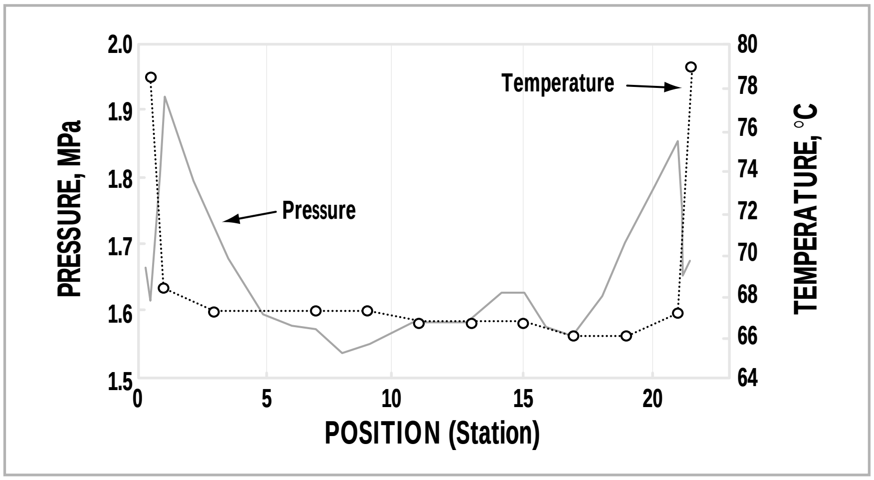
A mill was interested in reducing the end failures of its synthetic roll coverings and wanted to establish the proper amount of crown needed for its covered rolls. The most convenient time to take the nip impression was on startup, after freshly ground rolls were installed in the stack. The nip impressions showed an undercrowned situation at the bottom nip as shown by the line labeled “Cold” in **Fig. 1**. The amount of crown needed for a replacement cover was estimated from this nip impression taken at startup. The new roll was installed, and nip impressions were taken between reels after the stack reached normal operating temperatures. The nip impressions indicated an overcrowned situation, as shown by the line labeled “Hot” in Fig. 1.



5. Bulk progression for undercrowned queen roll



7. Micro-edge taper design (adapted from Ref. 2)



6. Hot ends

This case illustrates the point that nip impressions should be taken after the machine has reached operating temperatures because the rolls may develop thermal crowns. The thermal profile under steady-state conditions will be different from the profile at startup.

This practice (recording nip impressions after newly ground rolls are installed and the calender has come up to steady-state operating temperatures) is encouraged because the possibility that deviations in the nip impression results are due to roll wear may be eliminated. Furthermore, temperature readings across the roll faces should be recorded at the time that nip impressions are taken. This information offers insight concerning the correct crowns.

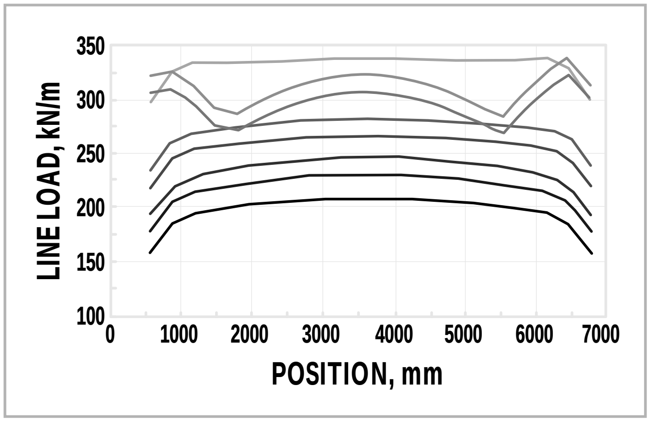
Stacks running unheated rolls: Cold ends

Internal heating is not used in many older stacks equipped with filled rolls. However, the filled rolls tend to get quite hot from internal hysteresis, and a heated sheet may also add energy to the rolls. The roll ends would often run cooler, since there was no sheet present to add energy and because heat may flow axially, as well as radially, out the ends. The resultant temperature profile would cause differences in the roll shape due to thermal expansion such that the roll would have a larger diameter in the middle than on the ends.

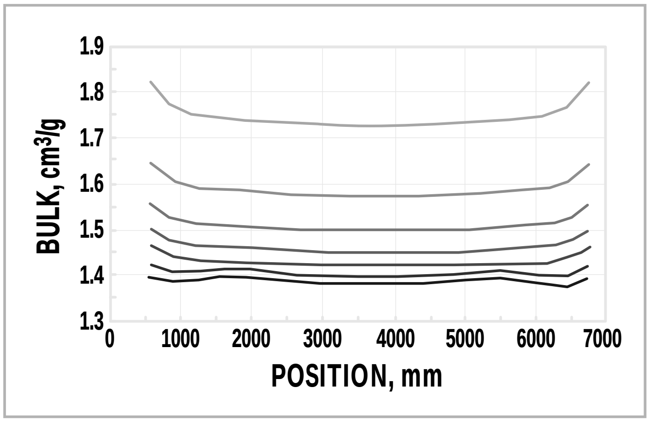
Hall and McLemore *(7)* showed that, while the temperature distribution across a single roll may be small, the sum of the distributions of all rolls in the stack may amount to a significant temperature variation. These thermal crowns could cause loading profiles similar to that shown in **Fig. 2**. Note that the loads are heavier in the middle than the ends. By applying Crotogino's calendering equation *(8),* one would expect that the ends of the sheet would have greater bulk than would the middle, as shown in **Fig. 3**. These thick ends are unacceptable for quality reel development. One way to overcome this problem is to intentionally decrease the crown of the Queen roll to develop the load profile that is shown in **Fig. 4**. One would then expect the bulk distribution shown in **Fig. 5**. This distribution is not perfectly uniform, but it is an improvement over the distribution obtained with the original Queen roll crown.

Stacks running heated rolls: End failures

A common challenge in calendering with heated rolls is hot ends. These end regions do not benefit from a sheet removing the energy from the roll. Additionally, the covered roll may actually contact the heated mating roll outside the sheet run. The result is that the ends of the roll will expand and will suffer greater loading. Too often, the



8. Heat-modified loading distribution



9. Heat-modified bulk distribution

10. Worn roll loading profile

cover fails. An example of increased end loading due to thermal expansion is shown in **Fig. 6**. The temperatures were measured using infrared temperature guns, and the pressures were recorded on Prescale film. This loading variation could have easily been avoided by proper edge relief.

Proper edge relief accomplishes two related goals. First, the nip loading will be more uniform. Second, the potential covered roll/heated roll contact outside the sheet edge, a primary cause of expensive cover failures, will be avoided. Ideally, one would grind a cover so that it has the desired shape profile at the steady-state operating conditions. Paasonen *(2)* wrote that "proper edge relief should start as close as possible to the sheet edge, and in critical thin paper applications a micro-edge relief construction is preferred." This micro-edge relief is illustrated in **Fig. 7**. The objective of this relief is to prevent overloading. Note that the gap between the paper sheet and the cover will not be present in actual operation, because the rolls will expand thermally to close the gap.

Intentional heating

The previous examples showed that the roll profile is related to the temperature profile and that the results of temperature profiles can be unfavorable. However, one can apply temperature profiles to correct the loading and bulk distribution. For example, air cooling may be used to reduce the end temperatures and combat hot-end problems in some applications. Zone-controlled induction heaters are gaining popularity since they may be used to control the roll profiles, and thus the load and sheet bulk profiles, and can add some energy to the sheet to aid the calendering process.

Consider the second example where the sheet bulk was higher at the ends due to cold ends on the calender stack. Instead of decreasing the crown on the Queen roll, one could instead apply inductive heating to the ends of the bottom intermediate roll and achieve the loading distribution shown in **Fig. 8**. This loading distribution would cause the bulk distribution to become more uniform, as shown in **Fig. 9**. For this case, the line load distribution never exceeded the design load, whereas reducing the crown on the Queen roll caused a large deviation in the line load distribution for the first nip.

Abrasive wear

Many ingredients of the paper sheet, including coating components, are highly abrasive. The rolls will wear more inside the sheet run and thus form relatively high spots outside the sheet run. These high spots will contact the mating roll, and high localized loads may result. For example, a mill began experiencing frequent end failures when it changed its coating composition to one that evidently had relatively higher abrasiveness. Cooling showers were applied to the ends of the rolls. The temperatures across the face and at the ends of the roll were reasonably uniform, but the nip impressions indicated severe overloads at the ends, as shown in **Fig. 10**. It was found that the covered roll diameter within the sheet run varied within 0.152 mm (0.006 in.), but the roll diameter was 0.36 mm (0.014 in.) greater at the ends of the roll than across the face of the roll. More aggressive end relief taper is necessary and may allow the covered roll regrind interval to be extended. Also, more frequent regrinding of the metal rolls in the stack may be necessary to accommodate the more abrasive coating.

Bad nip profile

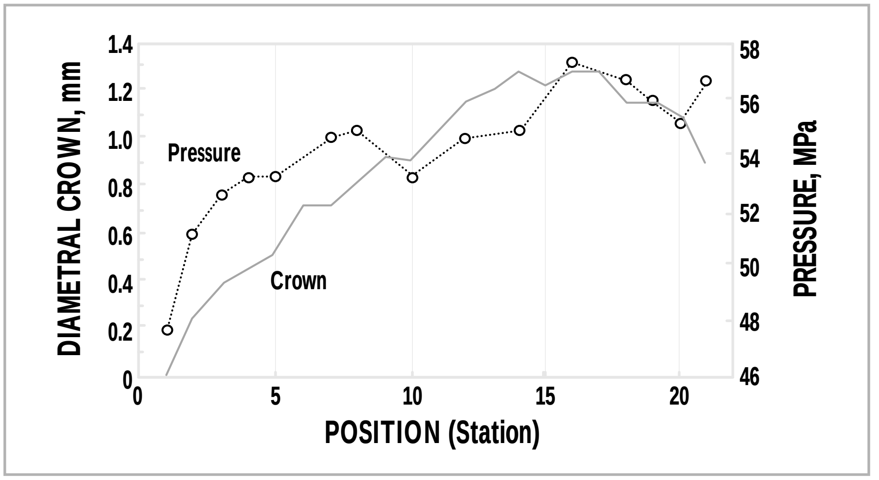
As stated by Paasonen *(2),* the radial indentation into a calender cover is very small, even at the high loads applied. The results of roll profile variations can be especially severe in a supercalender stack because of the cumulative effects of the multiple nips. Therefore, calender roll grinding tolerances must be much tighter than those typically applied to other paper mill applications. Our grinding specifications dictate that the crowns should be ground to within 0.018 mm (0.0007 in.). The same tolerance is used for station-to-station variations. These tight tolerances cannot be met unless the rolls are ground on precision bearings. All the rolls in the stack must conform to strict tolerance, and it is important to monitor the shape of the metal rolls.

An example of a poor roll profile and the resulting nip impression data are shown in **Fig. 11**. This carrot-shaped roll generated a distinct front-to-back loading differential.

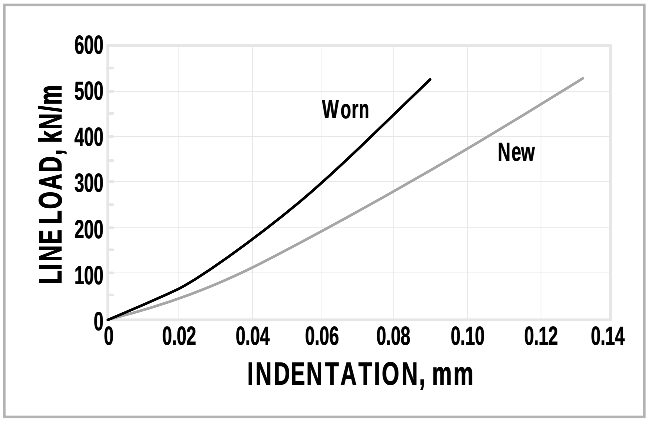
Profile, marking, and objects through the nip

In the previous example, we stated that the radial indentation in the nip is quite small in magnitude. This fact is illustrated in a plot of the load vs. indentation calculated for a typical calendering geometry in **Fig. 12**. Note that small increases in the amount of indentation are associated with relatively larger increases in the line load. This relationship reinforces several concepts presented in previous examples: A local profile change in diameter will change the local loading, and roll profile tolerances must be kept tight.

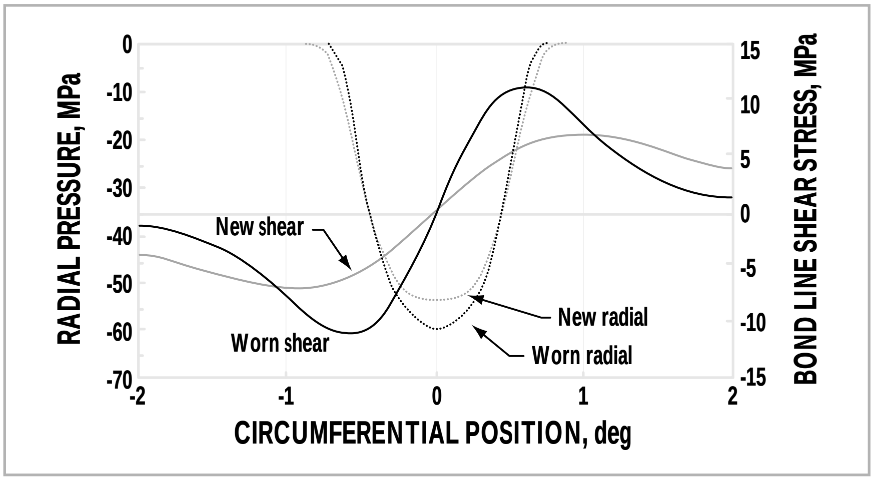
This relationship also illustrates that objects entering the nip result in huge line load increases. For example, one may apply Fig. 12 to estimate that a 0.05-mm (0.002-in.)-thick object running through the example



11. Effect of roll profile on load profile



12. Roll penetration



13. Cover stresses

nip loaded to 200 kN/m will increase the local line load by 233 kN/m to 433 kN/m for the new cover, which is already indented 0.065mm. For a cover whose topstock has been ground to half its original thickness, the object will cause a local line load over 525 kN/m. Unfortunately, high local stresses caused by relatively small objects, such as coating lumps and paper folds, can exceed the elastic limit of modern synthetic cover materials and cause permanent marking or more serious damage to the cover. Care should be taken to eliminate the sources of wrinkles and sheet breaks where possible. Inevitably, objects will run through the nips and will cause visible or invisible damage. Periodic cover regrinds can increase total cover life by removing surface damage and thus preventing a formed crack from propagating.

Thin covers

As a cover wears and is reground, its diameter is obviously reduced. This cover will be less of a cushion in the nip and will act stiffer than a thicker cover, as illustrated in Fig. 12. Additionally, the stresses within the cover will be increased, as shown in **Fig. 13**. This cover will be less forgiving to profile errors and to objects passing through the nips since these factors will further increase the stresses. Therefore, it is wise to place thin covers higher in the stack, where they are subjected to lower applied loads.

Cover selection

The primary components of a synthetic roll cover are the polymer matrix, fillers, and reinforcements. The maximum operating temperature of the roll cover will be determined by the glass transition temperature (thermoset, amorphous) or melt temperature (thermoplastic, semicrystalline) of the matrix. The mechanical properties of the cover that directly affect the nip pressure profile and speed differential in the nip will be determined by the combination of the matrix, fillers, and reinforcements. The cover materials, as well as the cover construction and even process parameters, will determine the cover's damage resistance.

Gloss and bulk reduction for a given sheet are a function of the nip pressure and temperature. The cover modulus and Poisson's ratio at the application temperature will determine the nip pressure for a given nip geometry and line load. For this reason, cover suppliers now provide data showing modulus as a function of temperature instead of simply providing hardness values. Knowledge of the required temperature and pressure to achieve the desired gloss and bulk reduction can now be used to select a cover based on its thermomechanical properties.

SUMMARY AND CONCLUSIONS

This paper discussed several conditions that are common to supercalender stacks. The examples demonstrated that temperature variations may lead to loading variations and that the temperature should be measured across the face of a roll as a preventative measure. Furthermore, nip impressions should be used regularly to provide a baseline pressure profile and to identify highly loaded regions. Many of the end loading problems could be avoided by the use of proper edge relief. The suggestions given in this paper have application in soft calendering in addition to supercalendering. Proper monitoring and corrective actions may lead to longer regrind intervals and cover life in addition to more uniform reels. **TJ**

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