

Hot soft-calendering of groundwood printing papers

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While strength properties and printability are improved using soft calendering advances in coating formulations and soft roll covers are needed before it replaces other finishing techniques in coated and uncoated groundwood papers.

We evaluated three different calendering methods—machine calendering, soft calendering, and supercalendering—in terms of the nip action and process variables. Here, we concentrate on the suitability of hard-nip and soft-nip calendering methods for uncoated and coated groundwood papers, including newsprint, uncoated, supercalendered (SC) papers, slightly coated machine-finished (MFC) paper, and lightweight coated (LWC) papers.

The discussion is based mostly on trial results obtained from a pilot machine calender, soft calender, and supercalender. Some soft calendering mill experiences are also cited.

Hard-nip and soft-nip calendering

The main differences in the nip action between hard-nip and soft-nip calendering are shown in **Table I**.

Hard-nip calendering

In hard-nip machine calendering, paper is compressed between incompressible steel rolls which form a short nip with a high specific nip pressure. The highest pressure is directed to high-basis-weight spots in the sheet, with low spots getting less treatment. Machine calendering tends to press the sheet to an even caliper.

Soft-nip calendering

Soft-nip calendering, on the other hand, calenders the sheet to a more even density because the soft roll has the ability to conform to basis-weight variations attributable to formation.

Supercalendering and soft calendering are both soft-nip calendering methods, with some distinct differences (**Table II**). The main difference is that soft calenders have only 1-4 nips, which are individually loaded, while

supercalenders typically have 8-11 nips, and even 15-17 nips on some specialty papers. To compensate for fewer nips, soft calendering is often aimed at high temperatures—up to 150-200°C on the heated roll surface.

Soft calendering of newsprint

Newsprint mills stand to reap undisputed benefits by using hot soft-calendering in terms of runnability in the printing presses and printability. A few newsprint machines have been started up or ordered with soft calenders in central Europe and Canada.

Newsprint is traditionally machine calendered, but the increasing use of four-color printing in newspapers requires a smoother and more even printing surface than what hard-nip calendering can produce. Some mills have been using very light supercalendering to improve printability. Supercalendering, however, causes the rigidity of paper to deteriorate, which lowers runnability in printing presses. Also, newsprint needs stiffness for better handling properties.

Strength means runnability

Figure 1 shows that machine direction (MD) tensile strength is preserved at a higher level in soft calendering than in hard-nip calendering. This means better runnability in the printing press.

Cross-direction (CD) tear is equally important for good runnability and is also maintained better in soft calendering (**Fig. 2**).

Figure 3 indicates that a very noticeable difference can be found in stretch values, as well, between machine-calendered and soft-calendered newsprint sheets. Stiffness values showed a similar trend.

Printability of newsprint

One way to evaluate printability from unprinted paper is to use roughness volume as an indicator for print uniformity. The lower the roughness volume, the smaller the ink demand, which also corresponds to more uniform print quality.

Figure 4 illustrates the meaning of roughness volume in calendering. To reach a given roughness volume, soft-

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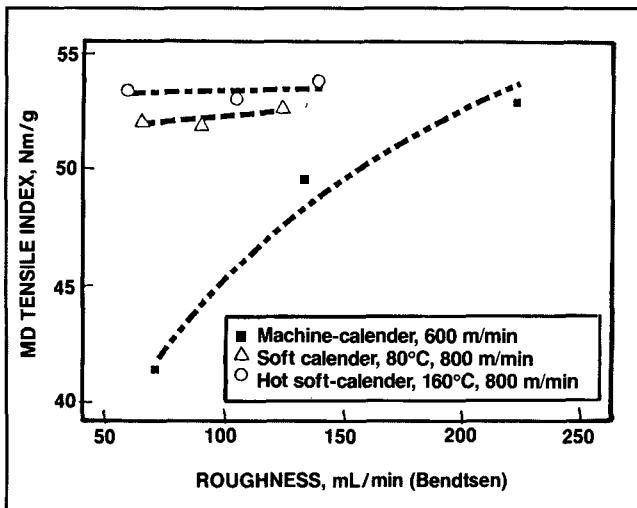
I. Principal differences between hard-nip and soft-nip calendering methods

	Hard-nip calender	Soft-nip calender
Rolls	Steel-Steel	Steel-Soft
Elements compressed in the nip	Paper	Paper and elastic cover
Calendering effect on paper	Uniform caliper	Uniform density
Nip width, mm	1-2	5-20
Maximum specific nip pressure, MPa	40-100	20-35
Constraints	High nip pressure causes uneven printing surface, glazing, and blackening	Durability of elastic covers

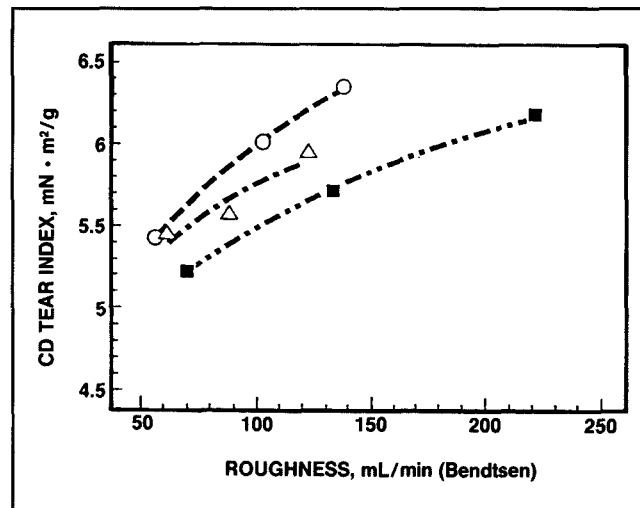
II. Basic differences between soft calendering and supercalendering

	Soft calender	Supercalender
Concept	On-line	Off-line
Number of nips	1-4	8-11 (up to 17)
Individually loaded nips	Yes	No
Linear load, kN/m		
Normal grades	Up to 300	Up to 350
Specialty grades	Up to 440	Up to 440
Temperature, °C		
Water	120-150	120-150
Thermal oil	250	NA
Speed, m/min	Up to 1500	Up to 1000
Soft rolls	Polymer rolls with good mark resistance	Cotton-filled rolls with poor mark resistance but high pressure capability
Number of units needed per paper machine	1	2-3

1. MD tensile index on 45 g/m² TMP-based newsprint in machine calendering and hot soft calendering



2. CD tear on 45 g/m² TMP-based newsprint in machine calendering and hot soft calendering



calendered paper can be rougher on the surface than machine-calendered paper.

In terms of printability, machine-calendered roughnesses of 70 mL/min and 100 mL/min correspond to soft-calendered roughnesses of 105-120 mL/min and 125-145 mL/min, depending on the hot-roll-surface temperature used.

Roughness tester comparison

Newsprint surface finish is expressed using several different smoothness or roughness tests. In Europe, the Bendtsen roughness is often used, while Parker Print-Surf (S10) is more common in the United States. Parker Print-Surf and Bendtsen roughness values do not correlate perfectly, especially at low roughness levels, and the degree of correlation is somewhat paper-grade related. Figure 5 presents the Parker Print-Surf roughness as a

function of Bendtsen roughness as measured in these trials.

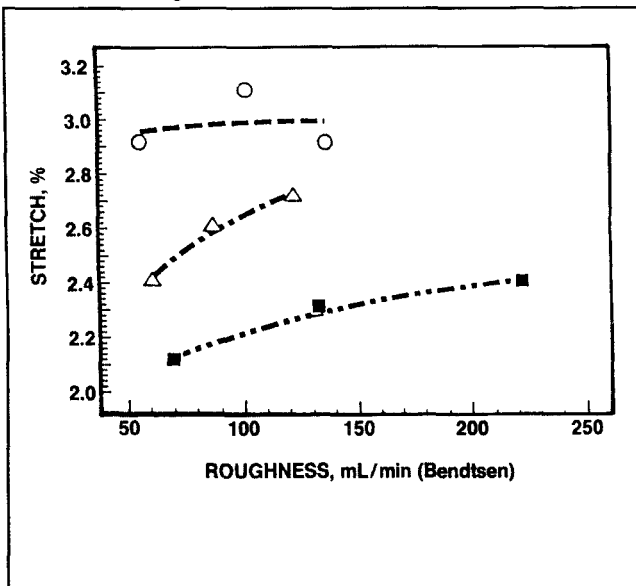
Benefits of soft calendering

In summary, soft calendering of newsprint gives the following advantages over machine calendering:

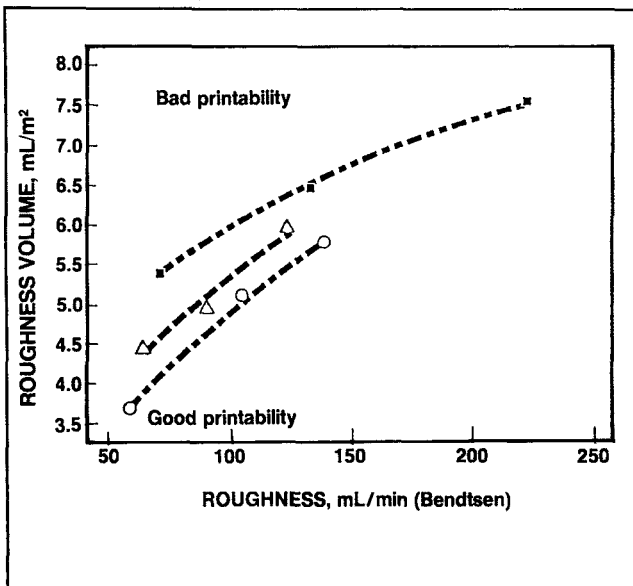
- Paper can be left rougher without deterioration of print quality.
- Improved print quality at the same roughness level
- All strength properties are better, even at lower roughness and better printability levels.
- Reduced danger for blackening at high moisture levels
- Soft nips are well suited to calendering of recycled fibers.

Currently, commercially acceptable roughness and print quality can be achieved at high speeds in two soft

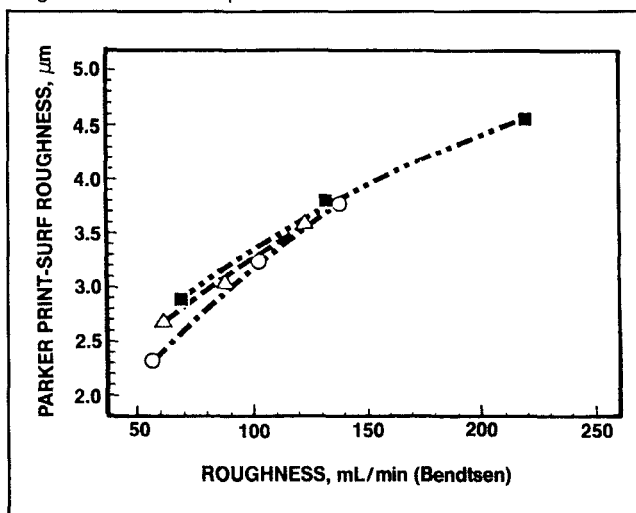
3. Stretch on 45 g/m² TMP-based newsprint in machine calendaring and hot soft calendaring



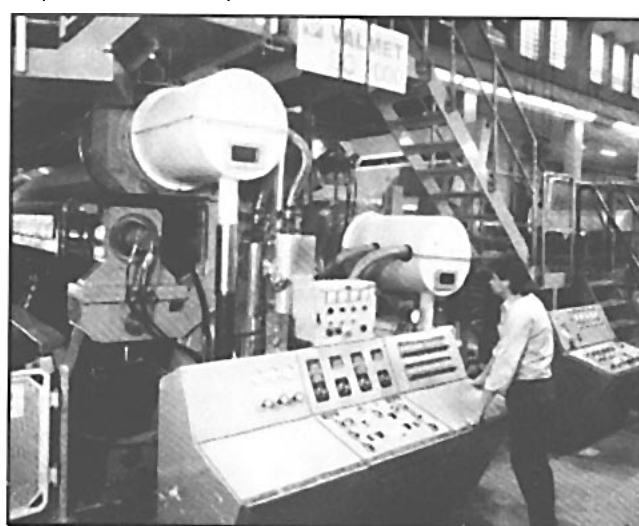
4. Roughness volume (printability) between machine-calendered and soft-calendered newsprint sheets



5. Correlation between Bendtsen roughness and Parker Print-Surf roughness in these newsprint trials



6. A two-nip on-line hot soft calender operating at 190°C surface temperature. Thermal oil joints on hot rolls are covered with large hoods.



nips using 90°C surface temperature and 250 kN/m linear load on typical European newsprint furnishes. High moisture content in the sheet combined with effective steaming will help (1).

For other furnishes, which are more difficult to calender [such as Canadian thermomechanical pulp (TMP)], a breaker stack may be needed as well as higher operating temperatures.

Cross-machine caliper profiling capability is a concern with soft calenders because soft nips tend to offset some of the attempted profiling action. Consequently, paper must have good dry profiles coming to the soft calender.

Uncoated SC papers

Uncoated, groundwood based, and clay-filled SC papers are normally finished on a 12-roll supercalender. A typical

56-g/m² SC-A rotogravure paper with a 26% filler content has a gloss of 40% and Parker Print-Surf roughness of 1.3 µm after supercalendering.

To reach the Parker Print-Surf roughness of 1.3 in soft calendering using only four nips, the following trial conditions were required:

- Soft calender speed of 600 m/min
- Hot-roll surface temperature of 200°C
- Linear load in all nips of 300 kN/m
- Initial sheet moisture of 8.7%.

This high soft-calendering temperature produces somewhat higher gloss than normal supercalendering, but brightness is sacrificed with high temperatures.

Current production soft calenders can safely run lightweight printing papers at normal paper machine

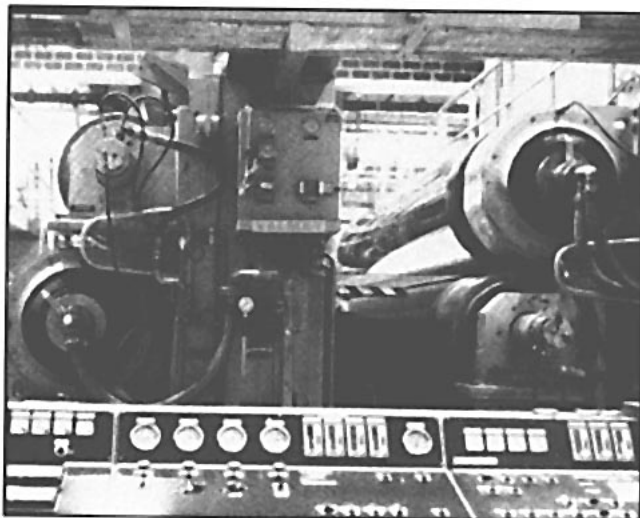
III. Hot soft calendering of 56-g/m² SC-A paper with 26% filler, using 150° C surface temperature

	Speed, 600 m/min		Speed, 1100 m/min	
	2 nips	4 nips	2 nips	4 nips
Roughness, Parker Print-Surf, μm	1.95	1.60	2.25	1.85
Hunter gloss, %	29.0	36.5	27.0	34.5

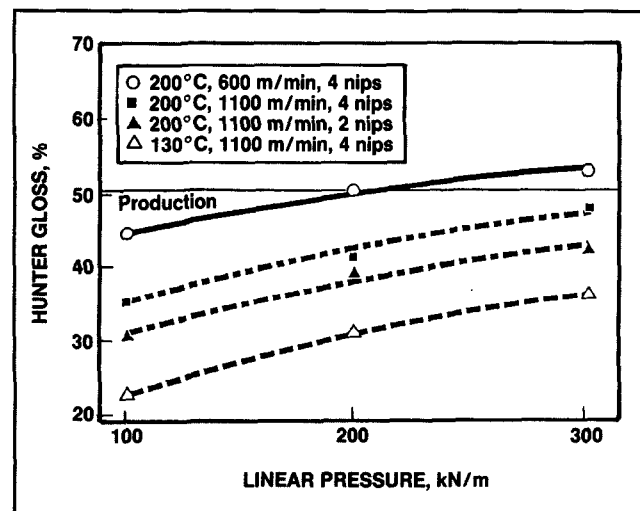
IV. Operating conditions and paper properties on 60-g/m² MFC heatset web offset paper in different calendering trials

	Type of calendering			
	Machine super-calendering	Soft super-calendering	Hot, soft super-calendering	Super-calendering
Number of nips	1	2	2	11
Heated roll surface temp., °C	60	60	150	75
Linear load, kN/m	150	150	250	310
Gloss, %	19	18	30	43.5
Parker Print-Surf, μm	3.06	3.04	2.28	1.50
Brightness, %	72.5	73.0	72.3	70.9
Opacity, %	92.6	93.0	92.5	91.8

7. A two-nip on-line soft calender in operation at a Finnish MFC paper mill



8. Hunter gloss in hot soft calendering of standard LWC offset



speeds and using 150–160°C hot roll surface temperature and 250 kN/m linear load. In these exact conditions, the soft calender will not produce a commercially acceptable surface finish on SC-A rotogravure paper (gloss 40, Parker Print-Surf roughness 1.3) as indicated in Table III.

There are several ways to improve the results, including:

- More effective calendering in a breaker stack position when the moisture content is high (using soft nips)
- More effective use of steam
- Improvements in the fiber furnish and filler quality
- Improved soft-cover materials for higher temperature and pressure durability.

Figure 6 shows a two-nip hot soft-calender in production.

Machine-finished coated papers

New MFC grades have recently been developed for heatset web offset printing. MFC paper is an on-machine coated and soft-calendered groundwood paper grade which, in many quality aspects, falls between SC-A and LWC. Some publishers call this type of paper LTC (lightly treated coated), the Japanese talk about SCP (slightly coated paper) or gate-roll-coated paper, and in the United States it is often referred to as No. 6 coated grade (2).

This intermediate grade seems to be suitable for newsprint mills with older machines. Recently, two Finnish mills rebuilt their 5.3-m newsprint machines to produce MFC. Both machines operate at 1000 m/min and finish the sheet in two single-nip soft calenders using nip pressures up to 180 kN/m and hot water temperatures of 80–120°C.

The interesting difference is that one mill uses stone-

groundwood-based furnish with about 50% kraft (Fig. 7), while the other mill uses TMP with only about 20% kraft. The TMP-based furnish provides somewhat higher bulk and opacity.

These two mills claim that stiffness, as a result of soft calendering, is maintained so well that the 54-g/m² SGW-based MFC and the 51-g/m² TMP-based MFC are both as stiff as 60-g/m² supercalendered LWC.

MFC grades are produced in the basis weight range of 51 g/m² to 80 g/m² with a coat weight of 6–8 g/m²/side. Parker Print-Surf smoothness is 2.5, brightness 75, and Hunter gloss around 15–20%, but printed gloss goes up to 45–50% because the z-direction strength is good, allowing the same high-tack inks to be used as are used on more expensive LWC papers.

MFC is a matte-finished, soft-calendered grade. Matte papers are typically machine calendered, but mottling may become a problem. Soft-nip calendering eliminates mottling.

Extensive pilot trials have been done on MFC paper comparing machine calendering, low-temperature soft calendering, hot soft-calendering, and supercalendering results.

No major differences can be found in MFC paper properties between machine-calendered and soft-calendered sheets, except that soft calendering produces a more uniform printing surface. Increasing the temperature to 150°C and linear load to 250 kN/m on the heated roll surface makes a difference in resulting smoothness and gloss. This confirms the fact that high temperatures are beneficial in producing good surface properties on coated paper.

Table IV presents trial results with different calendering concepts, including machine calendering, soft calendering, hot soft calendering, and supercalendering.

Further increasing the temperature in hot soft-calendering trials to 200°C and linear load to 300 kN/m and using two nips only brought the gloss level of MFC paper up to 45, which compares with supercalendered quality.

LWC papers

Some LWC paper producers are seriously considering the possibility of finishing LWC papers on-line, instead of supercalendering. Trial results indicate that the potential exists for successful on-line finishing, but it is going to require further development of both the calendering process and coating formulations before the on-line soft calendering of LWC papers is commercially viable (3).

Figure 8 illustrates that the gloss level of 52, which is commercially produced on a 10-roll supercalender, can be reached on a 4-nip soft calender, but only under quite tough operating conditions and at slow speed. This trial was done just to compare the results between supercalendering and soft calendering on a standard LWC offset paper.

When the speed of the pilot soft calender was increased to 1100 m/min, it was not able to produce the required gloss level. Commercial high-speed, soft-calendered LWC production will require a new look at coating formulations. Synthetic binder latices and plastic pigments are needed to more easily produce gloss and finish.

Summary

Hard-nip and soft-nip calendering treat paper differently. Strength properties—especially on newsprint—are better preserved in soft calendering. Print uniformity is another major benefit.

Soft calendering is currently used on MFC papers, but uncoated SC papers are supercalendered to reach the finish required. Trial results indicate that using very high temperature and nip load, but low operating speed, LWC papers could be finished with four-nip soft calenders. Commercial applications require a new look at coating formulations as well as good soft-roll covers for tougher operating conditions—in terms of speed, temperature, and nip load—than what is currently used at paper mills.□

Literature cited

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