Effects of shoe pressing on fine paper properties

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ABSTRACT

A series of trials has been conducted on a pilot paper machine to investigate the effect of shoe pressing on the web solids contents and properties of fine paper. The machine was operated at speeds of 600 and 700 m/min, and the shoe press nip load ranged from to 50 to 700 kN/m. Adequate bulk and a solids content of 45% were obtained when fine paper was pressed by two lightly loaded roll presses and a shoe press. Solids contents in excess of 47% were obtained when paper was pressed by four heavily loaded presses, one of which was a shoe press, but the bulk was about 10% lower than the bulk of paper lightly pressed in a three-roll press. Pressed to equal solids contents, paper pressed by a shoe press had a higher bulk and opacity, but lower Scott bond and strength than paper pressed in roll presses only.

Application:

Shoe presses should be considered for all new paper machines and for all major modifications of existing fine paper machines, because these presses can press the sheet to a high solids content with only a moderate product bulk loss.

THE INTENSITY OF WET PRESSING IS proportional to the magnitude and duration of the pressure pulse, but both of these parameters are limited for a nip formed by press rolls *(1)*. Some 20 years ago, this limitation was overcome by the development of a shoe press, which at that time could achieve about ten times greater linear load and about five times longer nip residence time than contemporary roll presses *(2)*. Since the first installation of an extended nip press (ENP) in 1980 *(3)*, many double-felted shoe presses have been installed, mostly on machines producing linerboard or other board grades. The first shoe presses were double-felted, and the resulting two-sided rewetting made such presses unsuitable for lightweight printing papers *(4)*. The application of single-felted shoe presses to printing papers had to wait until viable alternatives to granite press rolls became available, as these rolls could not sustain the heavy forces generated by the hydraulically loaded shoe presses. Early alternatives to granite suffered from excessive adhesion of wet webs and from problems with sheet release *(5)*. The first shoe press was installed on a newsprint machine in 1994 and on an uncoated wood-free paper machine in 1995 *(6)*. Shoe presses with ceramic-covered press rolls have become standard equipment on machines that are presently under construction for various printing grades.

The high solids content of webs pressed on heavily loaded shoe presses is the most obvious reason for the installation of these presses, but shoe presses offer several other advantages. For example, the majority of installations on linerboard machines has been motivated by the need to improves the product strength *(3)*. The retrofit of a shoe press onto existing machines may also result in higher machine speed and greater production capacity. Alternatively, the decreased drying demand can offer an opportunity to upgrade the machine, e.g., by converting it to unifelted drying or by adding a size press or a soft calender.

Preservation of product bulk might be an additional reason for applying shoe presses to paper machines producing printing papers and some board grades. The thickness of wood-free printing papers is often specified and, if the specification cannot be achieved by other means, the basis weight of the paper must be increased. Such a method of caliper control is, of course, very expensive.

The bulk of paper made from bleached kraft pulp is depressed by exposure to high pressure as the wet sheet passes through the sharp nip formed by two press rolls. Paper bulk can be slightly increased by unloading presses of fine paper machines *(7)*, but under these conditions, the high moisture content of the pressed paper can limit machine production capacity and increase the frequency of sheet breaks.

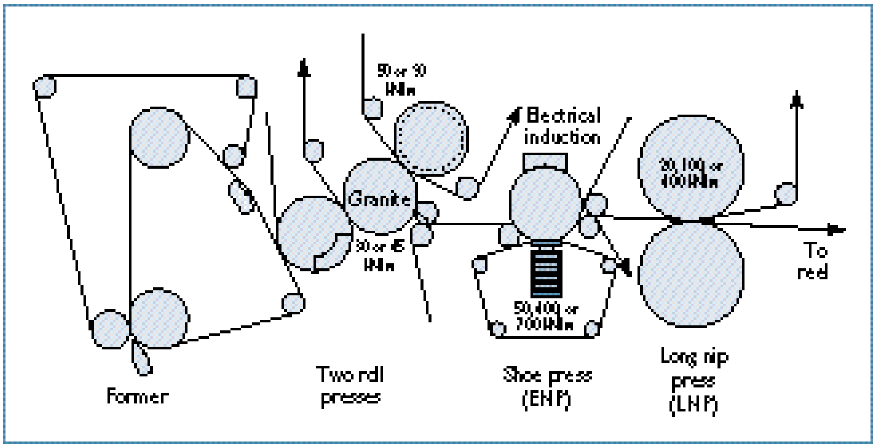
Mill experience demonstrates that the sheet is more densified in the sharp nips of presses formed by hard-covered or metal rolls than in nips formed by rolls with softer covers. Compared with a roll press, a modern shoe press typically has about a six times longer nip and operates with six times greater linear load, yet its maximum nip pressure is less than half of that generated in a roll press. Shoe presses reportedly can produce fine paper with equal bulk and higher solids content when compared with sheets pressed in roll presses *(8, 9)*, although these reports contained little specific data. The objective of this paper was to determine how pressing in a shoe press affects the properties of fine paper, with a particular emphasis on product bulk.

EXPERIMENTAL DETAILS

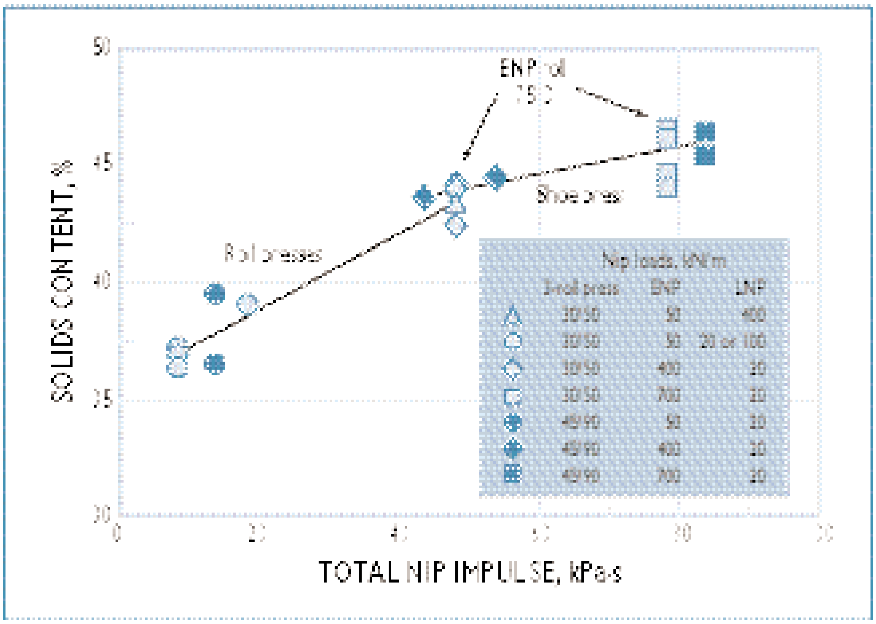
The experimental furnish was made from repulped fine paper supplied by a central Canadian mill. This paper was made from a bleached kraft pulp blend containing 80% hardwood and 20% softwood, with about 12% calcium carbonate. Paprican's pilot paper machine consisted of a roll/blade former followed by a pickup, three-roll inclined press; a shoe press (ENP); and a single-felted fourth press consisting of two 1.25-m-diam rolls forming a long nip press (LNP) (**Fig. 1**). The machine operated at 600 or 700 m/min.

The presses were loaded as follows:

- First two presses: 30 and 50 or 45 and 90 kN/m
- Shoe press: 50, 400, or 700 kN/m
- Fourth press: 20, 100, or 400 kN/m.



1. Scheme of the pilot paper machine

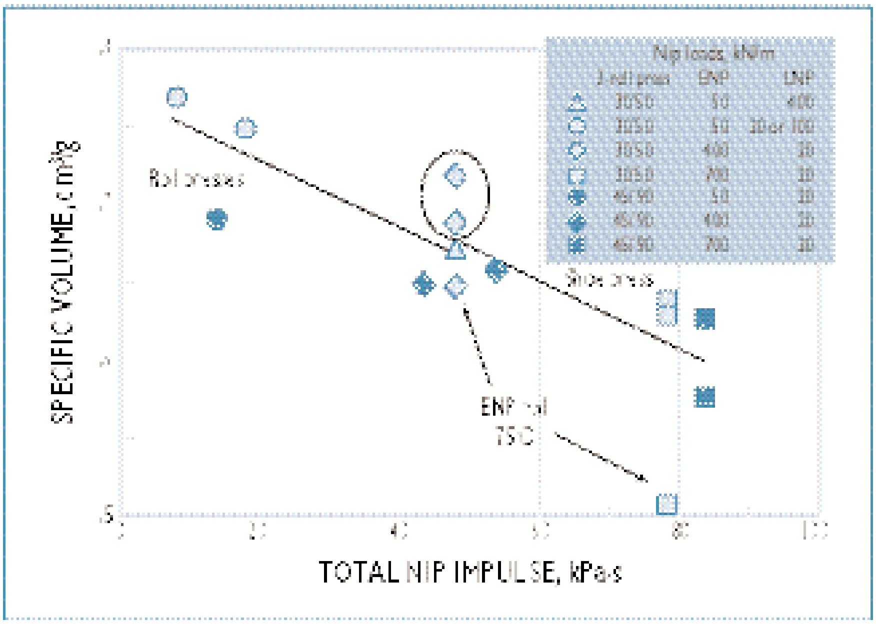


2. Web solids content as a function of total nip impulse of all presses. Symbols indicate various pressing conditions.

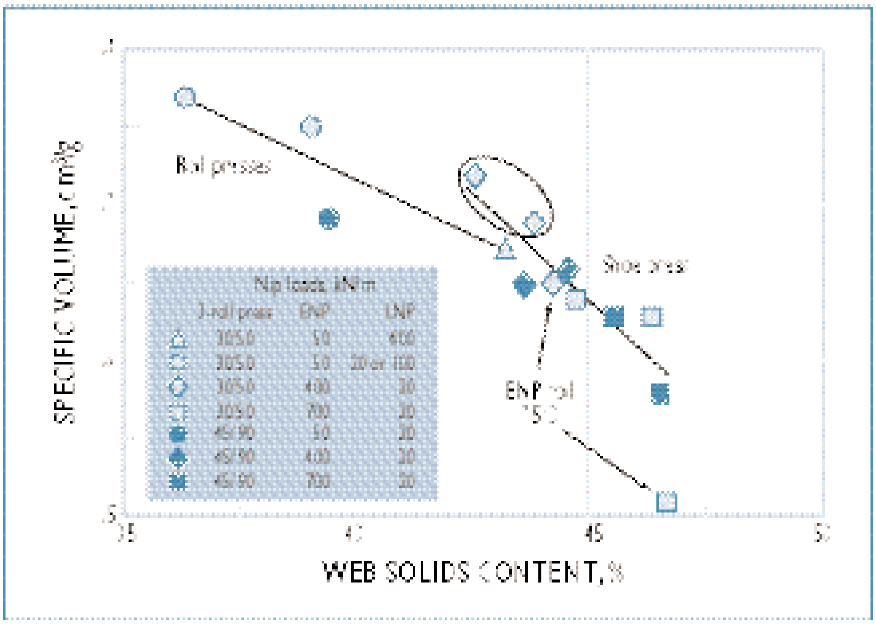
All four presses had to be closed to accomplish sheet transfer through the machine. The minimum load required to keep the presses turning was 50 kN/m for the shoe press and 20 kN/m for the fourth press. When operated at these minimum loads, the felts of these presses were not conditioned to ensure that they did not add or remove water in the press nip. At these minimum loads, the presses were assumed to have no significant effect on water removal or product quality. Felts similar to those used on commercial machines producing printing papers were used in all presses. The ENP and LNP were felted with Medium Duraply 300 (Albany International). Prior to this trial, the ENP felt was used for 45 hours and the LNP felt for 15 hours.

During the trials, the stock temperature was kept at 45–50°C. By the time the sheet arrived at the shoe press, the sheet's temperature dropped to about 35°C. To investigate hot shoe pressing, in some tests, the roll of the shoe press was heated to 75°C by electrical induction. As shown in Fig. 1, the heated roll was wrapped by the sheet for a distance of about 0.98 m to provide sufficient time (about 0.05 seconds) for sheet heating prior to the sheet entering the nip. The temperature of the sheet leaving the hot shoe press was about 55°C.

Pressed but undried paper was reeled; samples were cut from the reel and dried between two blotters in a photographic dryer. Paper produced between sampling periods was repulped and recirculated. Filler retention was low, as no retention aid was used during these trials. The ash content of the pilot machine paper was typically about 2%. During 5 days of trials, paper samples were collected under 21 pressing conditions, and some conditions were repeated to establish reproducibility. The nominal basis weight of the sheet was 70 g/m^2.



3. The specific volume of the sheet decreased with increasing nip impulse. The circled points appear to be the best compromise between the solids content and the sheet bulk.



4. Specific volume of uncalendered sheet as a function of the solids content achieved at various pressing conditions

RESULTS AND DISCUSSION

Solids content of the pressed sheet

The solids contents of sheets obtained at various pressing conditions are shown in **Fig. 2** as a function of the total nip impulse, i.e., the combined linear load of all presses expressed in kN/m, divided by machine speed in m/s. The two lines in Fig. 2 were fitted for the experiments in which only the roll presses were used (circles and triangles) and for the experiments in which two roll presses followed by a shoe press were used (squares and diamonds). As expected, sheets pressed at a higher total nip impulse had higher solids contents. Shoe-pressed samples were exposed to high nip loads and in general had higher solids contents than those pressed only by roll presses.

Press sections of many older machines consist of two two-roll presses, which consolidate the sheet to solids contents of about 40%. The data in Fig. 1 indicate that on such machines, the web solids content could be increased to about 44% by adding a shoe press operating at 400 kN/m, or to about 46% if the shoe press operated at 700 kN/m. Nip loads of 1000 kN/m are common on modern shoe presses, but pressing at these high loads was not attempted to avoid undesirable reduction of product bulk. Heating the ENP roll to 75°C caused only a minor increase in sheet solids content, but data collected in these trials are not sufficient for any conclusions about the effects of hot pressing. In an unpublished work, we obtained 1–2% higher solids content when a newsprint sheet was pressed in a hot shoe press nip.

Bulk of uncalendered paper

As expected, the specific volume of paper decreased with increasing total nip impulse used for pressing (**Fig. 3**). The circled diamond symbols correspond to paper that was pressed in the roll presses to a solids content of about 36% and then pressed in an ENP loaded at only 400 kN/m to a solids content that averaged 44%. These pressing conditions seem to offer the best compromise between solids content and product bulk. Increasing the ENP load to 700 kN/m increased the solids content by an additional 2%; however, it also caused a decrease of sheet bulk. This bulk drop is also clear from **Fig. 4,** which shows the specific volume as a function of web solids content obtained when pressing at various conditions. Again, the sheets pressed with an ENP loaded to 400 kN/m appear to offer the best compromise between solids content and bulk.

Pressing with a heated shoe press roll caused a further reduction in the sheet bulk.

Strength and optical properties

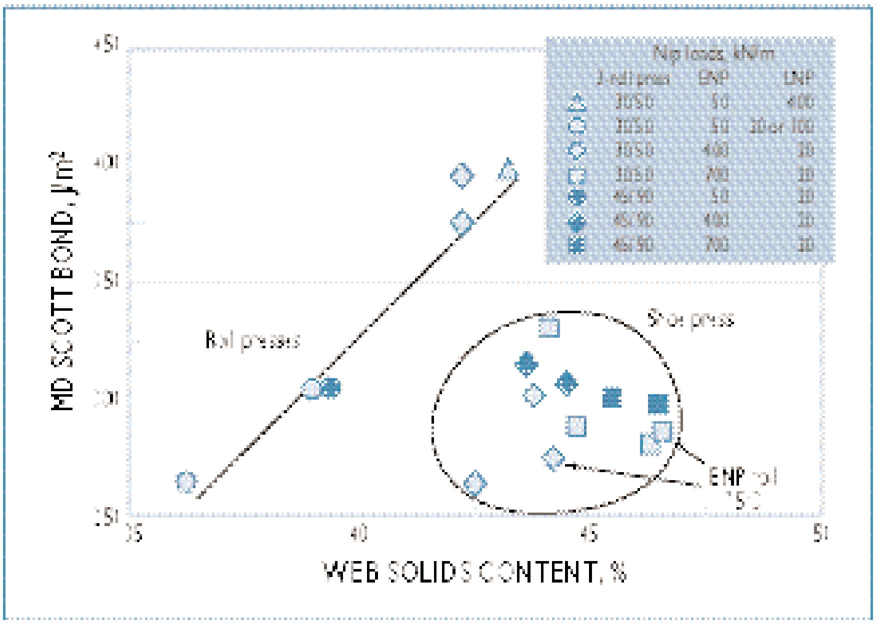
Scott bond is usually affected more by consolidation conditions and strength additives than by any other strength parameter. As shown in **Fig. 5,** when paper was pressed by roll presses only, the Scott bond of the paper increased proportionally with the total nip impulse. In contrast, shoe pressing increased the web solids content without substantially increasing the Scott bond strength. Apparently, the short but intensive pressure pulses generated in a two-roll nip densify the sheet and create good conditions for fiber–fiber bonding during drying. Heating the ENP roll had no significant effect on the Scott bond strength of the paper.

As a general rule, paper pressed to a higher web solids content in roll presses tends to be strong *(10, 11)*. An attempt to correlate the web solids content and the tensile strength of paper is shown in **Fig. 6.** The breaking lengths of samples pressed by two roll presses followed by an ENP were scattered but tended to be lower than values obtained for paper pressed to similar solids content with roll presses only.

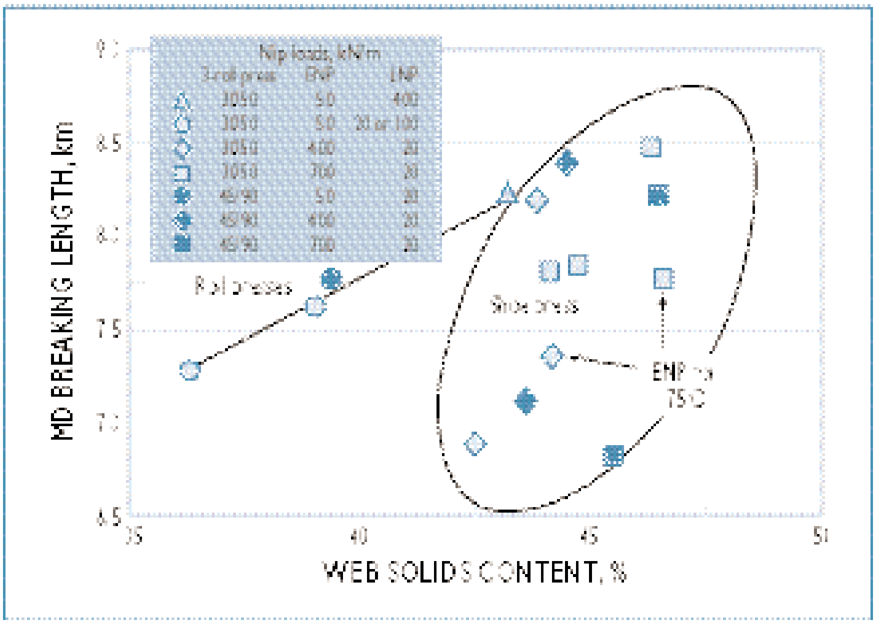
For samples pressed with roll presses only, there was a trend toward lower opacity for paper pressed to a higher solids contents (**Fig. 7**). There is no such clear trend among samples pressed by a shoe press, and pressing with a hot shoe press roll did not cause a drastic reduction in opacity.

Pressing with extreme load

In one experiment, the paper was pressed with the first two presses loaded to 30 and 50 kN/m, the shoe press loaded to 700 kN/m, and the long nip press loaded to 400 kN/m. The load of the last press was much higher than loads commonly used on last two-roll presses of machines producing printing papers, which usually do not exceed 120 kN/m. Paper with a solids content of 47.1% was obtained under these conditions. Dried paper had a specific volume of 1.58 cm^3/g, a Scott bond of 456 J/m^2, and a breaking length of 8.73 km. Thus, this very intensive pressing yielded paper with the highest strength but the lowest bulk.



5. The Scott bond strength of paper pressed in roll presses increased proportionally with the total nip load. Paper pressed in a shoe press had a lower Scott bond strength than paper pressed to a similar solids content in roll presses only.

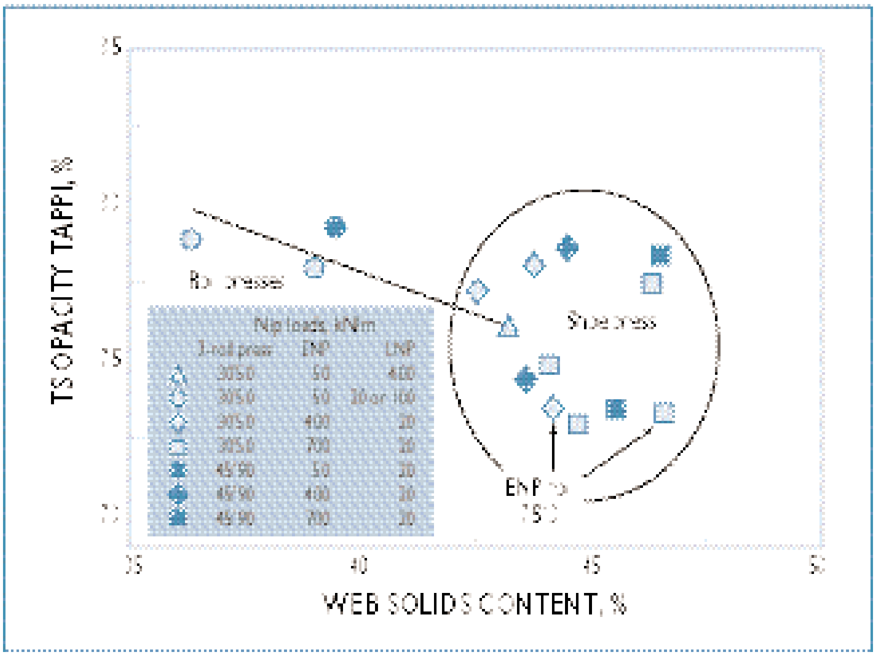


6. Tensile strength of paper pressed at various conditions. At equal solids contents, paper pressed with a shoe press tends to have lower tensile strength.

CONCLUSIONS

The following conclusions are based on the experiments that were conducted:

- Solids contents in excess of 45% can be obtained when fine paper is pressed in a shoe press.



7. The opacity of paper decreases as the sheet consolidation increases.

- The bulk of fine paper pressed at very high nip impulse is about 10% lower than the bulk of lightly pressed paper.
- Fine paper pressed with two presses and a shoe press tends to have slightly higher solids content and bulk, but lower Scott bond and tensile strength, than paper pressed at a similar total nip impulse using only roll presses.
- Pressing fine paper in a shoe press with the roll heated to 75°C caused only a minor increase in the web solids content and sheet density.
- Installing a shoe press on a drying-limited machine can result in a significant increase in its production capacity.
- Compared with roll pressing, shoe pressing of fine paper with a well-selected nip load can yield bulkier paper at equal solids content or paper with higher solids content at equal bulk. TJ

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LITERATURE CITED

1. Basher, L. H. and Cronin, D. C., *Pulp Paper Can.* 85(6):T138(1984).
2. Justus, E. J. and Cronin, D. C., *Tappi* 64(12): 35(1981).
3. Wicks, L., *Tappi J.* 66(4): 61(1983).
4. McDonald, J. D. and Pikulik, I. I., *Nordic Pulp Paper Res. J.* 43(3): 115(1988).
5. Pikulik, I. I., McDonald, J. D., and Aitcin, P. C., *Pulp Paper Can.* 94(4): T108(1993).
6. Schuwerk, W., *Das Papier* 49(10A):V106(1995).
7. Pikulik, I. I., McDonald, J. D., Mentele, C. J., *et al., TAPPI J.* 81(6): 122(1998).
8. Radtke, M. A., *Preprints of the CPPA Technical Section 79th Annual Meeting,* CPPA, Montreal, 1993, p. A221.
9. Lange, D. V., *Preprints of the CPPA Technical Section 72nd Annual Meeting,* CPPA, Montreal, 1986, p. B97.
10. Busker, L. H., *TAPPI Engineering Conference Preprints,* TAPPI PRESS, Atlanta, 1985, p. 117.
11. Bither, T. W. and Waterhouse, J. F., *Tappi J.* 98(11): 201(1992).