Wet pressing and product quality: Review of previous pilot machine trials

J. DAVID MCDONALD

ABSTRACT: The purpose of wet pressing is to remove water by mechanical means to consolidate the web and minimize the energy expended in the dryer section. In this process, paper is compacted and densified to degrees that impact end-use performance. Average density is increased by pressing, which has implications for grades where stiffness is important. The z-direction density gradients can affect printing and converting. Lastly, pressing affects surface quality of paper and its response to printing. Broadly speaking, the final press nip dominates the paper surface roughness and the early press nips affect printing performance.

Application: This paper describes how wet pressing affects the printability of paper. This information can be used to optimize existing press sections, understand the impact of press felt design, and to improve future press section design.

This paper is a summary of previous publications on the effect of wet pressing on product quality. Although this has not been an active field of research during the past twenty years, the topic remains important. Consolidating key past work from both laboratory experiments and extensive pilot paper machine trials into a single publication makes the results more accessible and has led to new insights and recommendations for press section design and operation. These studies include both laboratory and extensive pilot paper machine experiments.

AVERAGE DENSITY

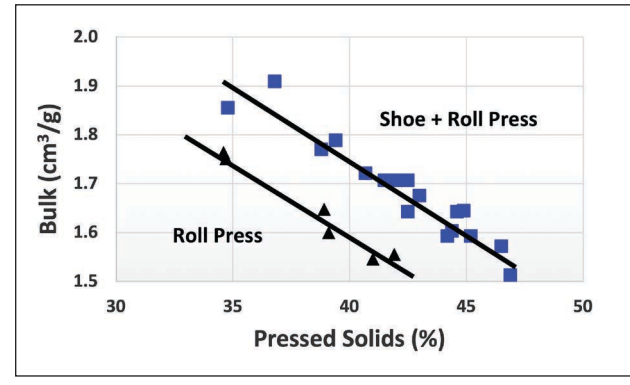
At the same pressed moisture, shoe presses can give a bulkier (less dense) sheet than roll presses [1-4], which is important for products where stiffness is required. This is probably related to a lower peak pressure in shoe presses compared to roll presses. For mechanical pulp-containing grades, the bulk difference is small [3], but for chemical pulp furnishes the bulk can be up to 10% higher for a heavily pressed product [1,2], as shown in **Fig. 1**. Higher press loads increase web density. However, excessive loads can cause web crushing and web breaks, typically in the first nip.

Surface roughness and density gradients

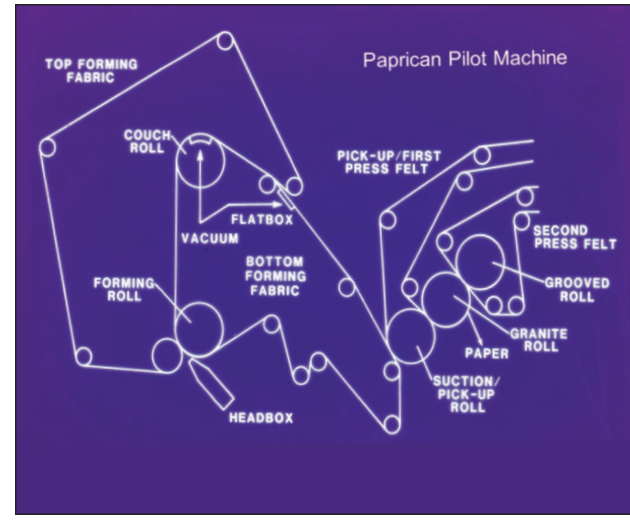
Many press nips are single-felted and thereby may create two-sided roughness by embossing one side with the felt and leaving the other side smooth due to contact with a smooth roll surface or belt [5]. In addition, because water flow is only through the felt side, density gradients in this surface are possible [6,7], which could affect printing and converting.

PAPRICAN PILOT PAPER MACHINE TRIALS

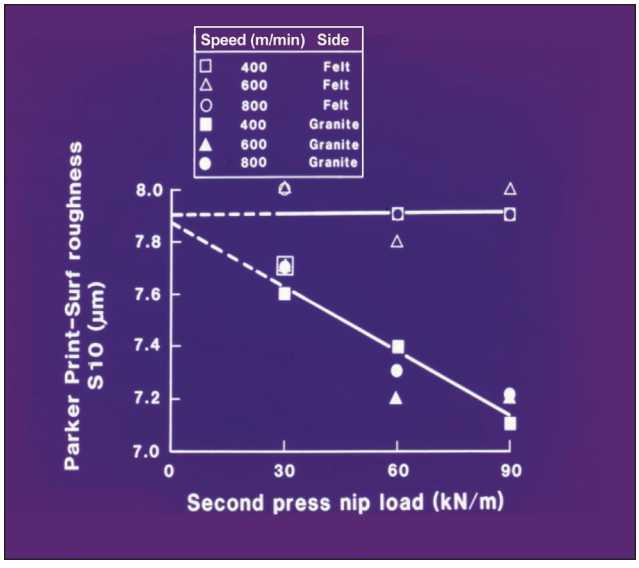
A series of pilot paper machine trials were carried out to evaluate the effect of pressing on paper roughness and



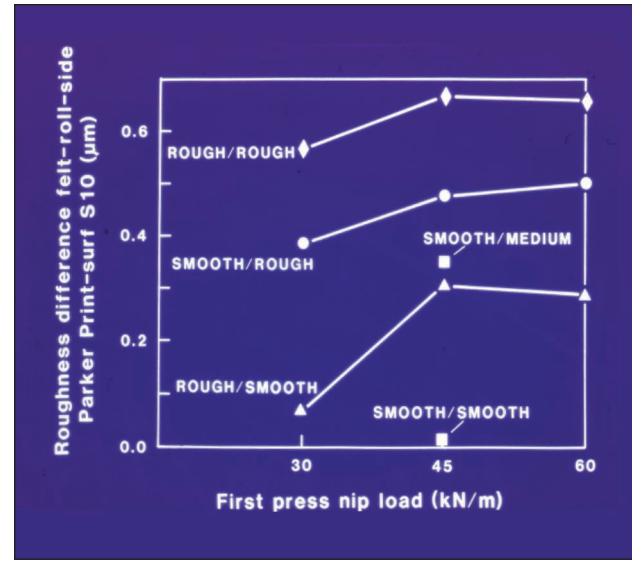
1. Increased pressing reduces the bulk of paper, but a shoe press gives higher bulk at the same pressed solids. Data is for a 60 g/m² fine paper furnish [1].



2. The Paprican pilot machine was configured as a roll-former, followed by a three-roll inclined press. The first and second nips are single-felted on the top side.



3. The roughness on the granite side of the paper decreased as the second press nip load was increased. The roughness on the felt side was independent of nip load. Note that the second press felt was a standard design for newsprint in the late 1980s. The paper was not calendered [8].



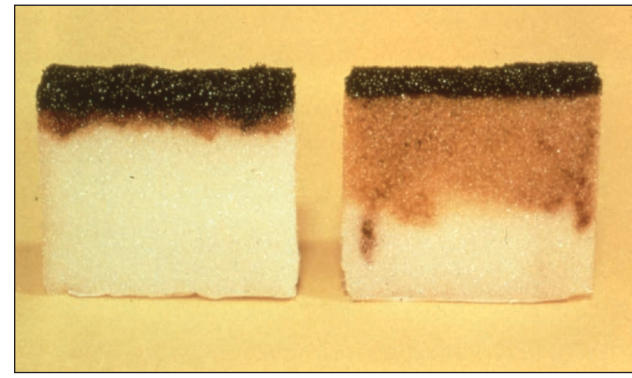
4. Roughness two-sidedness is plotted against first press load for pairs of first/second press felts constructed to give rough, medium, or smooth surfaces by using batt fibers of varying diameters. As expected, the rough/rough pair gives the greatest two-sidedness. There is no two-sidedness for the smooth/smooth felts [9,10].

printability, properties that are sensitive to surface densification. The Paprican pilot machine was configured as a roll-former followed by a three-roll inclined press using several felts with different roughness (batt fibers) on a newsprint furnish (**Fig. 2**).

Roughness

In the Paprican pilot machine, the felts are on the top side of the paper in both press nips, and the granite roll contacts are on the bottom side (Fig. 2). The felt designs were not specially fabricated for these experiments but were typical of those for newsprint machines of the late 1980s. As the second press nip load was increased (**Fig. 3**), the paper pressed against the granite side became smoother, whereas there was no change on the felt side, as measured by Parker Print-Surf [8].

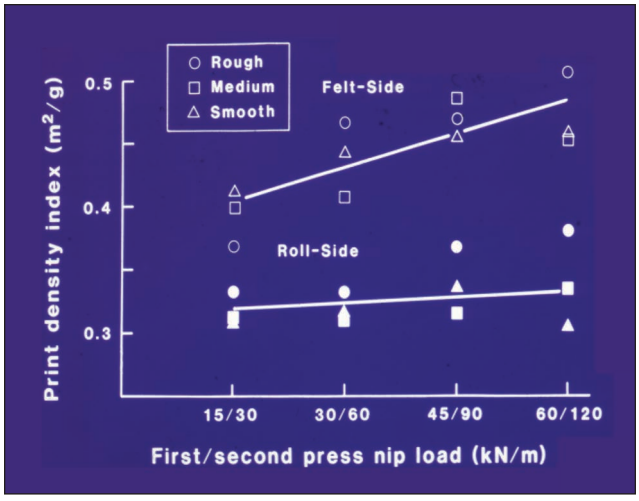
The degree of two-sidedness depends on felt construction (batt fiber diameter), as shown in **Fig. 4** and **Table I**. The greatest two-sidedness in roughness occurs when both first and second press felts are rough, but was eliminated when both felts are smooth. The second (last) press nip has the greatest impact on roughness [5,9].



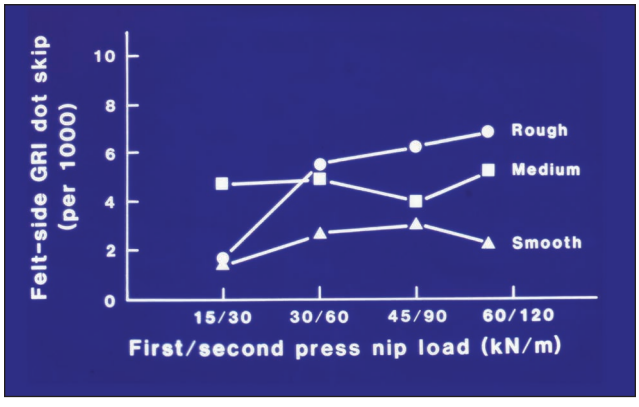
5. Print density is the blackness of the print divided by ink transfer. This concept is illustrated with Styrofoam cubes. With the ink confined to the surface, the cube on the left has a higher print density.

Designation	Press Position	Base Weave	Basis Weight, g/m²	Batt Fiber Diameter, µm
Rough	First	Double-layer	920	43
Smooth	First	Triple-layer	1040	19
Rough	Second	Double-layer	1200	43+27
Medium	Second	Double-layer	1340	43+27
Smooth	Second	Triple-layer	1070	17

I. Felt construction (from [9]).



6. As press loads on both presses were increased, the print density index of letterpress prints increased on the felt side of the paper, whereas the was no change on the roll side. Print density index was independent of felt design [10].



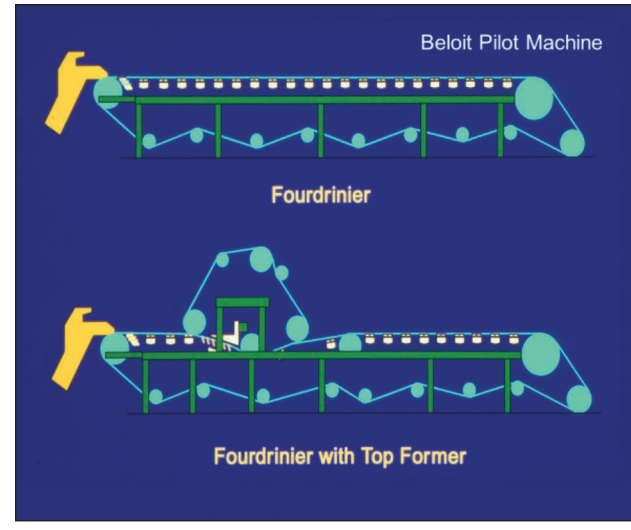
7. Missing dots on the felt side were related to felt roughness [10].

Print quality

The three traditional methods for high volume printing are: letterpress, offset, and gravure. In letterpress, ink is applied to a raised surface that is pressed against the paper. In offset, ink is transferred to a flexible, flat blanket that is pressed against the paper surface. In gravure, ink is contained in engraved cavities or dots. For the ink to be transferred to the paper in gravure, the ink meniscus must come into physical content with paper.

One measure of print quality is print density index, defined as the blackness of the print divided by the amount of ink transferred (**Fig. 5**). Higher print densities are an indication that the ink sits on the surface of the paper rather than penetrating within the body of the paper. This feature is important for printers, because it lowers the amount of ink used. It also contributes to the overall visual quality of the print.

In the Paprican trials, print density of letterpress prints increased on the felt side as the first and second press loads were increased (**Fig. 6**). This suggests that as more dewatering takes place on the felt side, a denser layer forms on the paper surface that resists ink penetration.



8. The wet-end Beloit pilot machine was configured as either a fourdrinier or a top-former.

The quality of the gravure prints was determined by printing with a Gravure Research Institute (GRI) proof press and counting missing dots [10]. The technique is described in [11]. The missing dots appeared on the felt side of the paper and increased with the roughness of the felts, independent of nip load, as shown in **Fig. 7** [10].

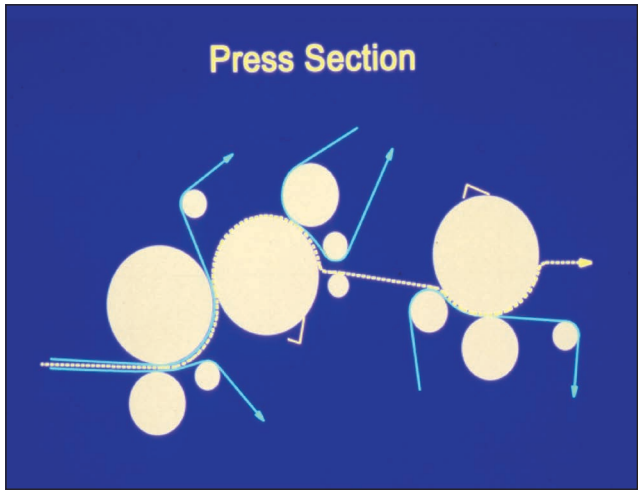
In gravure printing, the ink resides in 60-µm-dia. cavities in the printing plate. There needs to be physical contact between the ink meniscus and paper surface for the gravure dot to be transferred. The batt fiber diameters of the smooth, medium, and rough felts are 17 µm, 27 µm, and 43 µm (Table I), which can create surface depressions on the same order of magnitude as gravure dots. For this reason, the gravure dot skip measurements correlate with the batt fiber dimensions of the second press felts (Fig. 7). In addition, gravure dot skip and Parker PrintSurf measurements are correlated because the width of the air leak instrument's ring is 51 µm, which is similar to the depressions caused by the felt surface and the size of the gravure dots.

Summary of the Paprican paper machine trials

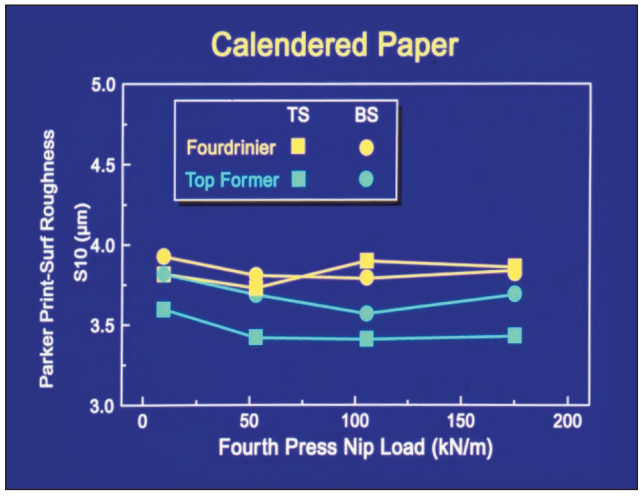
The roughness difference between the felt and roll side increased with nip load and felt roughness. The last press nip had the greatest impact. Print density increased with press load on the felt side, which suggests that the outer surface of the paper has been densified. The first press nip, which removes the greatest amount of water, has the greatest effect on densification.

BELOIT PAPER MACHINE TRIALS

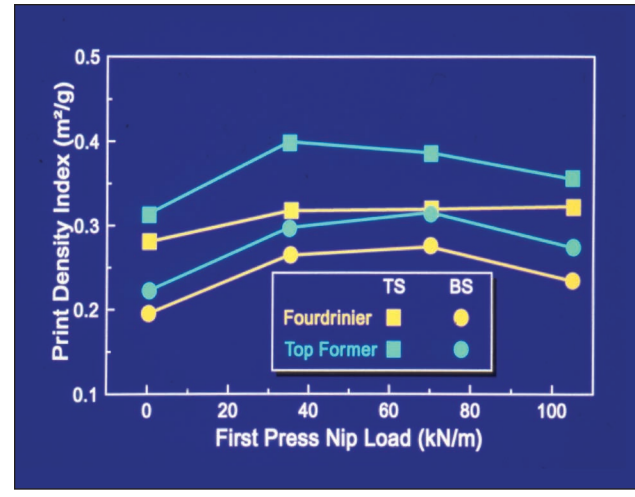
Subsequent to the Paprican trials, experiments were conducted using Beloit's pilot paper machine to understand the effect of heavy pressing on product quality, particularly with a fourth press [12]. The Beloit pilot machine was configured as either a fourdrinier or top-former (**Fig. 8**) with a four-roll press followed by a fourth press (**Fig. 9**)



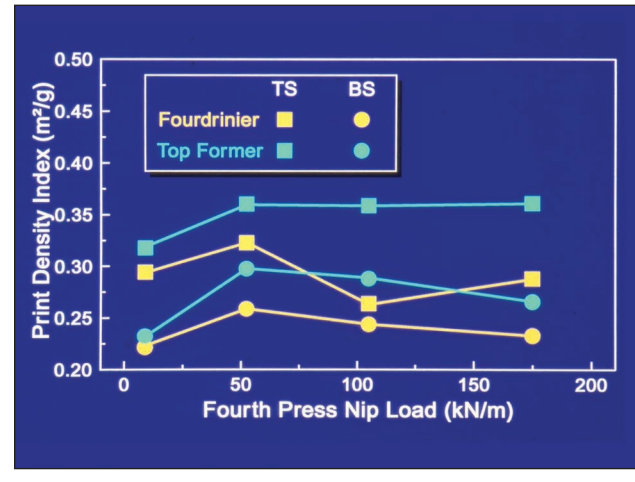
9. The press section on the Beloit pilot machine was a four-roll, three-nip press followed by a fourth press. The first nip was double-felted, the second and third nips had the felts on the top side, and the fourth press had the felt on the bottom side.



10. Top-former gives smoother paper than Fourdrinier. Loading the fourth press up to 50 kN/m increases the smoothness on both sides of the paper. The results are for newsprint [13].



11. Loading of the first press up to 70kN/m increases the print density on both sides of the paper [13]. With further loading, the print density and strength decreases, which is an indication of incipient crushing.



12. Initial loading of the fourth press increases the print density index on both sides of the paper [13].

on newsprint and a fine paper furnish. In both trials, press loads were varied to understand the impact on product quality.

Roughness

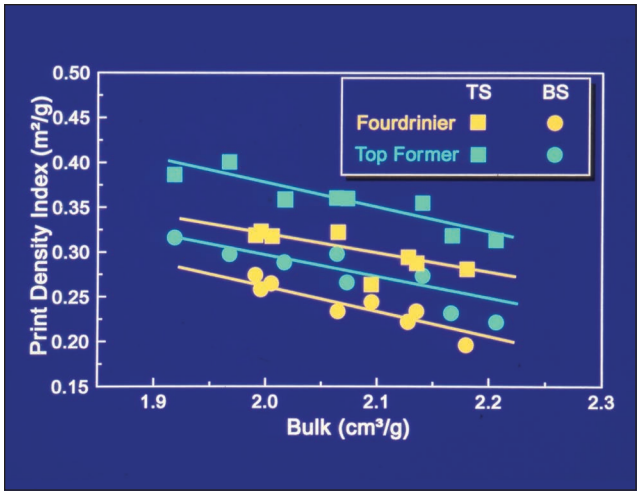
The newsprint from the top-former is smoother than the fourdrinier, but two-sided with a rougher bottom-side [13] (**Fig. 10**). Initial loading of the fourth press reduces the roughness on both sides of the paper for both formers, a consequence of the very smooth felt used in this position.

Print quality

Loading the first press up to 70 kN/m increases the print density on both sides of the paper because water is removed in both directions in the double-felted nip [13] (**Fig. 11**). At loadings above 70 kN/m, the print density decreases, as well as the strength properties [13], which is an indication of incipient crushing. The top-former gives a higher print density than the fourdrinier because of enhanced dewatering. The higher top-side print density is a result of top-side dewatering in the second and third press nips.

Initial loading of the fourth press increases the print density on both sides of the paper [13] (**Fig. 12**). As little water is removed in this press, this is likely the result of consolidation rather density gradient creation by water flow.

The addition of the top-former led to higher print density than the fourdrinier on both sides of the paper and marginally increased the two-sidedness (**Fig. 13**) [13]. The better print density on the top-side for both former configurations appears to be related to the second and third press top-felted nips because of surface densification caused by the direction of water flow.



13. Calendering improves the print density index, as bulk is reduced but cannot change the two-sidedness created in forming and pressing [13].

Although machine calendering can improve the print density on both sides of the paper, it cannot correct the two-sidedness created in forming and pressing, as shown in Fig. 13 [13]. The optimum strategy for paper machine design and operation would be to maximize consolidation in the early press nips, without crushing, to minimize consolidation necessary in the calender. Densification in the press section will increase both print density and strength properties [13,14], whereas calendering will increase print density, but paper strength is reduced. Greater levels of pressing will also reduce the linting tendency for offset printed paper [15].

Summary of the Beloit trials

Former design has the greatest effect on sheet properties, but the impact of the press nips is significant. In particular, print density that is developed in the second and third single-felted nips can cause two-sidedness. The felt side of newsprint becomes rougher with pressing [13] and is even more noticeable with fine paper [14]. Increased press loading increases dry strength, except at extreme nip loads where incipient crushing takes place [13,14].

CONCLUSIONS

Wet pressing can have a significant affect on product quality. For chemical pulp-containing grades where stiffness is important, a shoe press can give a 10% higher bulk than a roll press at the same pressed solids content. Paper surface roughness and two-sidedness are primarily determined in the last press nip. The "smoothness" of the felt is critical, because embossing from the felt surface layer of batt fibers can lead to dot skip in gravure printing. Print quality, as measured by print density index, is related to the quantity and direction of water flow in the press nip. This means that the early nips, which remove the majority of the water, are most critical for z-direction density gradients. If these nips are single-felted, this will lead to two-sidedness in print density. **TJ**

LITERATURE CITED

1. Lange, D., "Shoe pressing of paper grades," *TAPPI Papermakers Conf.*, 1996, p. 437.
2. Pikulik, I.I., *TAPPI J.* 82(11): 88(1999).
3. Pikulik, I.I. and Hamel, J., *TAPPI J.* 83(8): 88(2000).
4. Krochak, P. and Östlund, C., "The effect of press nip geometry on dryness, density and paper properties," in *Advances in Pulp and Paper Research, Trans. of the XVIth Fund. Res. Symp. Oxford, 2017* (W. Batchelor and D. Söderberg, Eds.), FRC, Manchester, 2018, pp. 323-423.
5. Pikulik, I.I. and McDonald, J.D., *Tappi J.* 70(4): 75(1987).
6. Szikla, Z. and Paulapuro, H., *J. Pulp Pap. Sci.* 15(1): J11(1989).
7. MacGregor, M.A., "Wet pressing research in 1989—A historic perspective, analysis, and commentary," *Trans. 9th Fund. Res. Symp. Cambridge, September 1989* (C.F. Baker, Ed.), Mechanical Engineering Publications, London, 1989.
8. McDonald, J.D. and Pikulik, I.I., *Pulp Pap. Can.* 89(3): T101(1988).
9. McDonald, J.D. and Pikulik, I.I., *Tappi J.* 72(11): 71(1989).
10. McDonald, J.D. and Pikulik, I.I., *Pap. Technol.* 31(8): 20(1990).

ABOUT THE AUTHOR

The research here has important implications for the design and operation of paper machine press sections. This paper consolidates findings that were originally published in a number of papers, making the information more accessible to researchers, papermakers, and paper machine designers.

I discovered that pressing can lead to two-sidedness in printing, and most surprisingly, that wet pressing can significantly affect printability. The most difficult aspect of this research was that it involved extremely complex paper machine trials.

For mills, the information here demonstrates how the design and operation of paper machine press sections affect the printability of the final product. A next step would be to use this information in the design of press sections.

McDonald is president at JDMcD Consulting Inc., Vaudreuil-Dorion, QC, Canada. Email McDonald at McDonald.jdavid@gmail.com.



McDonald

11. Dunfield, L.D., McDonald, J.D., Gratton, M.F., et al., *J. Pulp Pap. Sci.* 12(2): J31(1986).
12. McDonald, J.D. and Pikulik, I.I., *Tappi J.* 74(9): 159(1991).
13. McDonald, J.D., Pikulik, I.I., Mentele, C.J., et al., *TAPPI J.* 81(6): 131(1998).
14. Pikulik, I.I., McDonald, J.D., Mentele, C.J., et al., *TAPPI J.* 81(6): 122(1998).
15. Wood, J.R., McDonald, J.D., Ferry, P., et al., *Pulp Pap. Can.* 99(10): T350(1998).

ABOUT THIS PAPER

Cite this article as:
McDonald, J.D., *TAPPI J.* 19(7): 369(2020).
https://doi.org/10.32964/TJ19.7.369

DOI: https://doi.org/10.32964/TJ19.7.369

ISSN: 0734-1415

Publisher: TAPPI Press

Copyright: ©TAPPI Press 2020

About this journal

