HOW IMPORTANT IS WATER ABSORBENCY IN NEWSPRINT?

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Abstract: The surface chemistry of a newsprint was modified to cover the range from rapid water saturation to complete water repellency. In letterpress printing, differences in print quality with an oil-based ink were due to differences in surface structure (roughness) and not surface chemistry. In a two-colour offset printing trial with newsprints of the same physical structure but widely differing water absorbency, no signs of ink refusal, mottle, or other differences in print quality were seen across the range of samples. The possible influence of newsprint water absorbency on runnability problems such as misregister in multi-colour printing is discussed.

INTRODUCTION

In the past, the water absorbency rate of newsprint has not been a matter of concern to either the printer or the papermaker. This was true not only for oil-based letterpress inks, but also in single-colour offset printing. However, with the rapid growth in process colour offset printing, where four times the amount of water of single colour printing is placed on the paper, and with the current interest in water-based inks for existing printing processes, such as gravure and especially flexography, it is becoming increasingly important to understand the effect of surface chemistry on print quality and press runnability.

There is a considerable amount of printing plant experience to show that runnability problems such as misregister, curl, and wrinkling in offset pressrooms are related to excessive or uneven water absorbency. However, systematic studies of this type of problem are only just beginning. Water is believed to be the "trigger" that releases built-in tensions.

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While there is a considerable amount of information available on the stresses that develop in paper as it dries under tension, and as dry paper is strained [1, and references cited therein], the effect of furnish and paper machine variables on changes in paper stresses that occur as the paper is re-wet under tension is an area where study is only just beginning. Some work has already been done both at Paprican [2,3] and abroad [4,5]. In particular, Linna and Lindqvist [5] have described a non-contact device based on an acoustic sensor that can measure web tension during actual press operation. Skowronski and Lepoutre [2] showed that debonding, internal stress redistribution, and fibre swelling can all occur when a thin film of water is applied to paper, and are greater in more absorbent newsprints [3]. Although the amount of water applied in their work was double or more the amount of water applied in a four-colour offset press, the implications for the investigation of dimensional changes during offset printing are obvious. However, in the present report, the emphasis is on the effect of surface chemistry on print quality.

In earlier work [6-8], we looked at the surface chemistry of newsprint and its effect on high speed wetting. The newsprints examined covered a range from samples made completely water-repellent by deliberate self-sizing to extremely water-absorbent newsprints that had been treated with surfactant. In this report, we examined the effect on print quality of the modification of the surface chemistry of these newsprints.

EXPERIMENTAL

Letterpress Print Quality Study

Letterpress printing studies were done on newsprint samples covering a range of surface chemistry and surface structure (Table I). A GFL laboratory rotary press was used for ink transfer to these samples, according to SCAN standard P35:72 [9]. Prints were first made at increasing ink levels, in order to determine the ink requirement of the paper. The prints were then repeated with set off to a reference paper. Reflectances were measured with an Elrepho photometer in order to calculate print density (PD), print through (PT), and set off (SO), all according to SCAN standard P36:77 [10]. The print density index (PDI), print through index (PTI), and set off index (SOI) were calculated according to the method developed by Mangin and De Grâce [11]. Sample descriptions, GFL SCAN standard test results, and printing efficiency calculations are shown in Table 1.

TABLE I
NEWSPRINT SAMPLES USED IN LABORATORY LETTERPRESS PRINTING

Sample Treatment	*PPS Roughness, μm (S_{20})*	*Y_{max}, g $^{m-2}$*	*PD_{max}*	*PT_{max}*	*SO_{max}*
50°C Calendering					
Untreated, water-sprayed only	2.58	2.16	0.971	0.060	0.317
0.15% nonionic surfactant	2.33	2.01	0.924	0.057	0.336
0.60% nonionic surfactant	2.51	2.14	0.943	0.062	0.367
0.15% anionic surfactant	2.62	2.07	0.925	0.057	0.332
0.60% anionic surfactant	2.58	2.07	0.958	0.054	0.303
Untreated	3.05	3.29	1.006	0.075	0.411
0.60% cationic surfactant	3.07	2.93	1.004	0.066	0.344
0.60% nonionic surfactant	2.93	3.50	1.026	0.074	0.466
Self-sized (hydrophobic)	3.84	5.45	1.091	0.096	0.543
0.15% nonionic surfactant added after self-sizing	3.53	4.02	1.035	0.081	0.397
0.60% nonionic surfactant added after self-sizing	3.11	4.12	1.034	0.087	0.467
100°C Calendering					
Untreated, water-sprayed only	2.24	1.69	0.880	0.055	0.354
0.15% nonionic surfactant	2.18	1.73	0.941	0.062	0.354
0.60% nonionic surfactant	2.06	1.66	0.875	0.054	0.343
200°C Temperature Gradient) Calendering					
Untreated, water-sprayed only	2.22	1.39	0.869	0.062	0.367
0.15% anionic surfactant	2.15	1.45	0.865	0.056	0.374
0.60% anionic surfactant	2.19	1.43	0.849	0.048	0.363
0.15% nonionic surfactant	2.19	1.26	0.817	0.049	0.340

Offset Print Quality Study

The newsprint used in offset print quality trials was an eastern Canadian Fourdrinier paper containing 20% low yield sulfite pulp and 80% stone groundwood pulp. Because of its high content of hydrophobic extractives (1.7%) and its high alum content (640 ppm as Al), this newsprint self-sized appreciably on storage at 23°C. Varying degrees of self-sizing up to complete water repellency were obtained by accelerated aging at 105°C for up to 24 hours. Air-atomized aqueous solutions of a common nonionic surfactant, Triton X-100 (Rohm and Haas), were sprayed onto this newsprint before calendering. Calender speed, surfactant concentration, and flow rate were adjusted such that 0.07, 0.15, and 0.3 gm^{-2} of surfactant were added. In this way, twelve levels of water absorbency were obtained in the same newsprint, from complete water repellence to rapid saturation. The twelve samples included four with different levels of self-sizing, three self-sized samples with varying amounts of surfactant added after self-sizing, two unaged samples, and three unaged samples with wettability further increased by surfactant addition.

These twelve newsprints were spliced (as 200 m lengths) into a single roll, together with other control samples. The roll was run at 470 m/min in the Paprican research offset press [12] in the two-colour mode. Only fountain solution was applied in the first colour unit. The time between first and second printing units was approximately 50 ms. The roll was cut up after printing, and the print density and show through were measured. Printed samples were also visually examined for non-uniformity.

Dynamic Sorption Measurements

The high speed sorption of water and of typical newsprint fountain solutions was measured by using the dynamic sorption apparatus described previously [13,14]. The dynamic sorption of a mineral oil typical of news ink vehicle oils was measured on two different newsprints calendered to a variety of roughnesses. This oil had a viscosity of 0.103 Pa.sec (or 103 cP) measured on a Haake falling ball viscometer, and a surface tension of 30.7 mNm^{-1} measured by pendant drop photography. The total internal pore volume and the pore size distribution of the papers were determined by mercury intrusion porosimetry [15].

RESULTS AND DISCUSSION

Sorption of Fountain Solution

There was no difference between the sorption of water and the sorption of the water-based (alcohol-free) fountain solutions commonly used for newsprint (Figure 1). This was as expected from earlier work [16], where it was found that while newsprint-type fountain solutions might show a low surface tension in an equilibrium measurement, surface tensions measured under dynamic conditions were much higher, and were close to that of pure water.

Sorption of Mineral Oil Vehicle

It is well known that a non-polar liquid will penetrate a non-swelling porous structure following a square-root time dependence, such as that predicted by the Lucas-Washburn equation [17]. Various authors (e.g., [18]) have

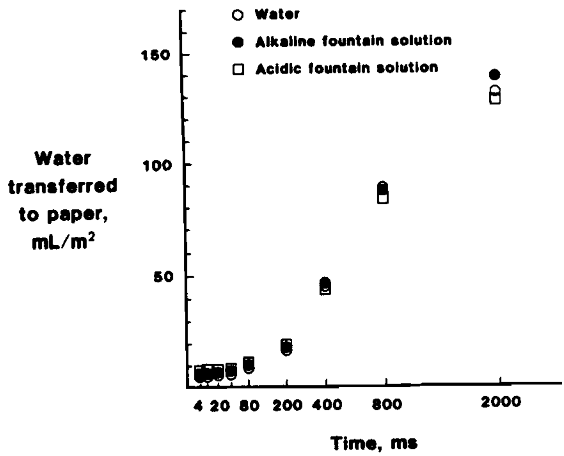

Figure 1. High speed sorption of water and offset fountain solutions on newsprints.

modified the basic Lucas-Washburn equation for the non-ideality of paper; especially its finite pore volume and its tortuosity (defined as the ratio of the total length of pores to their projected length). Assuming that the contact angle between the oil and the paper is zero, the depth of penetration is expressed as in equation 1, where: V/A is the depth of penetration (volume/unit area) of the oil in time t, r is the mean pore radius, γ is the surface tension of the oil (30.7 mN m^{-1}), η the viscosity of the oil (0.103 Pa.sec), ε the void fraction of the paper, and τ the tortuosity.

$$\frac{V}{A} = \frac{\varepsilon}{\tau} \left(\frac{r\gamma t}{2\eta}\right)^{\frac{1}{2}} \qquad (1)$$

Absorption in the dynamic sorption test has always been assumed [6,7,13,14] to obey equation 2. In this equation, k_r is the volumetric roughness, or the amount of liquid that fills the surface voids of the paper before sorption can begin, and k_a is the slope of the sorption curve.

$$\text{Absorption} = k_r + k_a t^{\frac{1}{2}}, \text{ for } t > \text{wetting delay} \qquad (2)$$

The average mean pore radius r and the void fraction ε were determined by mercury intrusion porosimetry. Since tortuosity could not be determined from the present data, it was assumed that tortuosity is inversely related to caliper. This is a reasonable assumption when dealing with a single newsprint calendered to different levels and so the inverse of the caliper was substituted for τ in Equation 1. The measured sorption coefficient in Equation 2, K_a, was plotted against the constant terms in Equation 1, $\varepsilon/\tau \ (r\gamma/2\eta)^{\frac{1}{2}}$. Correlation coefficients R^2 of 0.81 and 0.83 were obtained for two different newsprints. Data for one newsprint are shown in Table II. Had a better estimate of tortuosity been available, and had the experimental k_a values been more precise, an even better fit could presumably have been obtained. Nevertheless this result shows, for non-interacting and non-swelling fluids, the relationship between the parameter defined by Equation 2 and fundamental sorption theory described in Equation 1.

TABLE II
DYNAMIC OIL SORPTION

Caliper mm	*Void fraction*	*Specific pore volume, cc g^{-1}*	*Mean pore radius, μm*	*Width of pore radius distribution at half maximum, μm*	*k_a,* $mLm^{-2}\ sec^{-1/2}$*
0.124	0.414	2.51	1.6	2.6	43.4±6.7
0.103	0.513	2.08	1.6	2.8	34.9±9.0
0.094	0.514	1.90	1.5	2.5	33.9±4.7
0.088	0.508	1.78	1.4	2.2	29.8±4.7
0.081	0.515	1.64	1.3	1.8	29.4±2.7
0.078	0.487	1.58	1.0	2.1	26.9±2.8
0.076	0.492	1.54	1.1	2.1	26.0±3.0
0.073	0.523	1.47	1.1	2.1	25.9±3.4

** 95% confidence limits; contact time 0.2 to 0.02 seconds.*

Ink Transfer and Letterpress Print Quality

Since changes in surface chemistry affecting water absorbency can also affect oil and ink absorbency, it was first necessary to examine transfer and setting of an oil-based ink across a range of water absorbency levels. The "print density index", "print through index", and "set off index" developed by Mangin and De Grâce [11] allow the normalization of laboratory proof printing results of samples manufactured or calendered under different conditions. Results are shown in Table I and Figures 2 - 4. The data from a large number of samples differing in both water absorbency and physical structure fall on a single curve, similar to that shown by Mangin and De Grâce for samples of identical water absorbency but different physical structures. Water absorbency is therefore unimportant in the transfer of an oil-based ink, even over a wide range of surface chemistries.

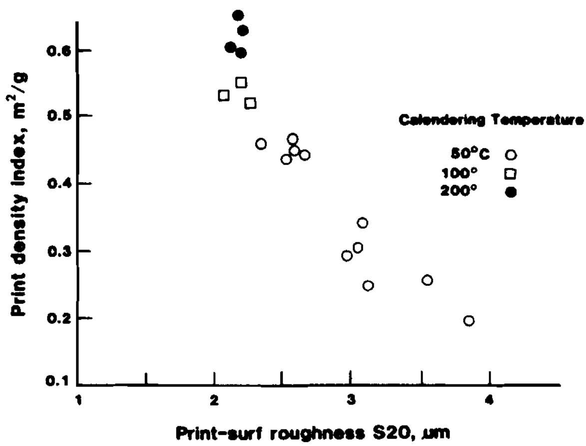

Figure 2. Print density index of newsprints of widely varying water absorbency and surface structure. These results are the same as those obtained from a set of samples with the same wide range of surface roughness but with identical water absorbencies, showing that transfer of an oil-based ink is controlled by surface structure.

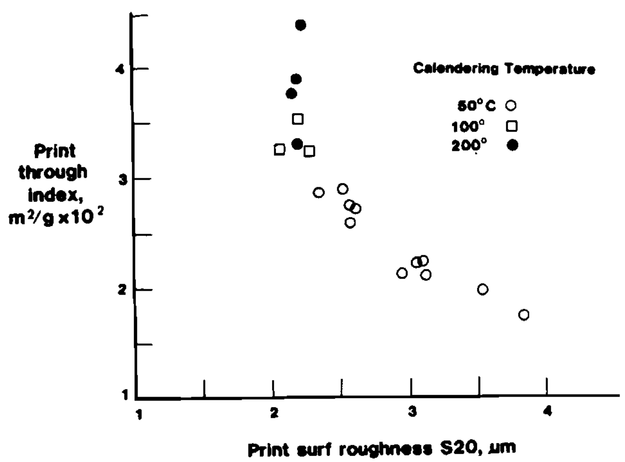

Figure 3. Print through index as a function of newsprint roughness.

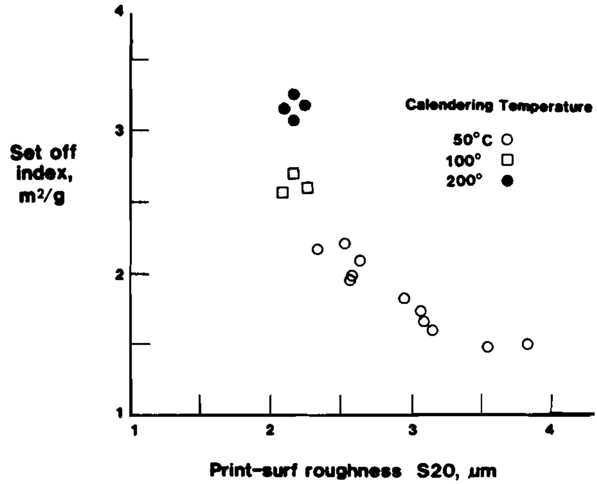

Figure 4. Set of index as a function of newsprint roughness.

Offset Print Quality

The print density and show through were identical, within experimental error, among all the samples in the roll made by splicing together newsprints of different surface chemistries. There were no signs of ink refusal or other forms of non-uniformity in any of the samples. Therefore, since all of the samples had the same surface structure, these results demonstrated that water absorbency was not important to two-colour offset printing of newsprint.

The principal mechanism of ink transfer to newsprint is hydraulic impression into surface pores [e.g., 19]. Under these conditions of forced penetration, there is no need for wetting. We know from dynamic sorption measurements [13] that even a heavily sized or self-sized newsprint can immobilize a considerable amount (the equivalent of up to 10 µm thickness) of liquid in its surface structure. We therefore assume that even the most heavily self-sized newsprint can hold the applied fountain solution within its surface structure, and that on a surface as rough as newsprint, water does not interfere with ink transfer. Whether water is physically adsorbed or absorbed within the fibres may be important to the dimensional stability of the paper, but not to ink holdout.

This finding is contrary to what is observed with coated paper where water absorbency is known to affect ink transfer in multi-colour web offset [20]. What happens with intermediate grades such as highly filled supercalendered groundwood specialties has not yet been determined.

Initial Moisture Content, Water Absorbency and Ink Holdout

Newsprint is always manufactured to a set moisture content. To avoid confusion, it should be noted that within the normal range of newsprint moisture contents, the rate of water absorption is little affected by the initial moisture content [13]. There is so far no inconsistency between the observation in the previous section that water absorbency has little effect on ink holdout, and the relatively secondary influence of initial moisture content for which, as yet, no systematic studies have been done.

How Necessary is it to Control the Water Absorbency of Newsprint?

So far, the discussion has centered on the observation that surface chemistry had little effect on print quality of letterpress and offset newsprint. In what way, however, would adjusting surface chemistry change runnability in the press room? It should be noted that different rates of water sorption are believed to indirectly affect print quality by changing the ink-water balance on the press, and to affect runnability by increasing the amount of water picked up by the paper.

In process colour offset lithography, the surface chemistry must, like other paper properties, be uniform in both machine and cross-machine directions. On the Paprican research offset press, even when there were no print quality differences among newsprints with modified surface chemistry, it was sometimes difficult to maintain a constant web tension due to CD non-uniformity in water absorbency resulting from non-uniform pretreatment of the web.

Recycled newsprint furnishes tend to be extremely water-absorbent, due to the loss of hydrophobic wood extractives during washing, and the possible presence of residual surfactants from the deinking process. This excessive water absorbency is blamed by various pressrooms and newsprint mills for a variety of runnability problems. Several newsprint mills using large amounts of recycled pulp have tried or are currently using various sizing agents to reduce the water absorbency of their product.

Although alum addition to a normal newsprint furnish is normally sufficient to cause a significant decrease in water absorbency [6,8], alum has much less effect on recycled pulp due to the reduced amount of natural resin and fatty acids which react with the alum to produce hydrophobic aluminum soaps.

Offset linting has long been suspected [21] of being influenced by water absorption. The "conventional wisdom" here states that repeated absorption of water weakens the paper surface, making it more susceptible to damage by the tack force of the splitting ink film. Recent work [12] has suggested that this is not completely correct, although repeated wetting of the paper surface will of itself remove more lint. We attempted to look at the effect of changes in surface chemistry in a given furnish on offset linting. However, owing to the difficulty of obtaining such samples commercially, or of preparing them uniformly on a laboratory or pilot plant scale, we have not yet been able to obtain conclusive results on the effect of surface chemistry on linting.

Finally, the potential for the growth of water-based flexography in newspaper production should be kept in mind. The influence of newsprint properties on quality and runnability in flexo has only just begun to be investigated. We have so far [22] seen only minor variations in flexo ink holdout with major changes in newsprint surface chemistry. More work is needed, on newsprint samples prepared under controlled conditions, to show just how much print quality and ink holdout are affected by surface chemistry. Owing to the novelty of water-based flexo and the lack of production information obtained from routine press runs over extended periods, it is too early to tell what influence surface chemistry may have on other runnability problems such as curl, misregister, and wrinkling.

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REFERENCES

1. Dodson, C.T.J., and Herdman, P.T., in "The Structure and Physical Properties of Paper", Rance, H.F., ed., Volume 2, Chapter 7, Elsevier, 1982.

2. Skowronski, J., and Lepoutre, P., Tappi 68 (11), 98 (1985).

3. Skowronski, J., and Lepoutre, P., Pulp and Paper Report 541, 1985.

4. Falter, K.-A., Adv. Printing Sci. and Technol., 17, 347 (1984); Falter, K.-A., Adv. Printing Sci. and Technol., 18, 112 (1986).

5. Linna H., and Lindqvist, U., in "Newsprint and the Pressroom -- II", ANPA/CPPA, Chicago, 1985, p. 193.

6. Aspler, J.S., Davis, S., and Lyne, M.B., Tappi 67 (9), 128 (1984).

7. Aspler, J.S., and Lyne, M.B., Tappi 67 (10), 96 (1984).

8. Aspler, J.S., Chauret, N., and Lyne, M.B., in "Paper-making Raw Materials", Proceedings of the Eighth Fundamental Research Symposium, Oxford, 1985; Mechanical Engineering Publications Ltd., London, p. 707.

9. SCAN P35:72, "Test Printing of Newsprint in the GFL Rotary Test Printing Press", Scandinavian Pulp, Paper, and Board Testing Committee, May, 1972.

10. SCAN P36:77, "Newsprint, Evaluation of Test Prints", Scandinavian Pulp, Paper, and Board Testing Committee, October, 1976.

11. Mangin, P., and De Grâce, J., International Printing and Graphic Arts Conference, Niagara Fall, NY, 1984, p. 135, Tappi Press, Atlanta.

12. Mangin, P., manuscript in preparation.

13. Lyne, M.B., and Aspler, J.S., Tappi 65 (12), 98 (1982).

14. Bristow, J.A., Svensk Papperstid., 70 (19), 623 (1967).

15. Ritter, H.L. and Drake, L.C., Ind. Eng. Chem. Anal. Ed., 17, 782 (1945).

16. Aspler, J.S., Davis, S., and Lyne, M.B., J. Pulp & Paper Science, in press.

17. Washburn, E.W., Phys. Rev., 17, 273 (1921).

18. Lepoutre, P., Paper Technol. and Ind., 19 (9), 298 (1978).

19. De Grâce, J.H., Mangin, P.J., Adv. Printing Science and Technol., 17, 312 (1984).

20. Hollingsworth, R.L., Jones, J.E.P., and Bonney, C., Tappi Coating Conference Proceedings 1983, 9.

21. Lebel, R.G., and Peterson, R., Pulp & Paper Canada, 81 (12), T350 (1980).

22. Aspler, J.S., Tappi Journal (in press), 1987.