The Effect of Paper Sizing Treatments on DOD Ink Jet Printing at Medium to High Resolution

J. Borch
Lexmark International, Boulder, Colorado

Abstract

Using dynamic penetration testing it is shown that acid-made, rosin-sized xerographic paper brands tend to show limited liquid uptake in the subsecond time frame required for full color ink jet printers presently marketed for that application. However, text printing requiring limited ink amounts is crisp and well-defined due to surface uptake only or limited capillary sorption. Alkaline-made, syntheticsized plain papers show more variation in liquid uptake. Some of these papers much better resemble the coated papers, marketed for highest grade color output, in their ability to take up ink during the subsecond time frame. Here, text and graphics printing suffers somewhat in providing more fuzziness in character and line definition. A careful analysis of the dynamic penetration plots shows that the degradation in character and line print quality is due to fiber swelling immediately at onset of penetration. This is supported by photomicroscopy of individual ink dots printed. The consequences of this for plain papermaking and ink formulation are presented. A novel, fast procedure for assessing the wettability of plain xerographic grade paper brands is described.

Introduction

Previous work[1] carried out describing paper-ink interactions in drop-on-demand (DOD) ink jet printing at medium to high resolution showed pronounced differences in penetration rates for both acid-made, rosin-sized paper brands and alkaline-made, synthetic-sized brands. However, as a group, synthetic sized brands were more likely to provide the ink volume uptake in the short time frame that is needed for full color printing with minimum bleeding between adjacent color areas. This was then achieved at the expense of increased text raggedness due to fiber feathering when using limited ink amounts for text printing. Using dynamic penetration testing, the present work analyzes the penetration process in more detail and in particular defines differences in penetration modes during the very short time interval (<100 msec). Drop testing will be used as a more qualitative means of identifying paper brands of specific wettability.

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Experimental

Ink-Paper Interaction Characterization

Printing of single ink jet drops were carried out using an IBM Color Jetprinter 4079*.

The quantitative uptake of one of the inks (yellow) was measured using a Noram Bristow Tester following the previous procedure[1,2]. This averages over sheet-to-sheet variation for packaged cut sheet mill brands and generally will provide an accuracy similar to that of TAPPI procedures used for routine testing of commercial paper. All data presented in this paper are for wire sides only.

Using the same ink and samples of the paper used for Bristow testing, drop testing was carried out applying 0.004 ml drops on the sheet surface. The penetration modes were evaluated as described in the following section (Results and Discussion).

Results and Discussion

Dynamic Penetration

Bristow plots for an alkaline-made No. 4 Xerographic paper brand and an acid-made No. 4 Xerographic paper brand are compared to that for the coated paper marketed for the printer in Figure 1. The latter provides optimum print quality for both text and color without text raggedness or color bleed. The two plain papers were not specifically intended for ink jet printing. In fact, they were identical brand names, marketed for similar performance in copiers and laser printers and non-distinguishable from each other by the end user. At present, this is common practice when paper companies are marketing the same brand name manufactured at different paper mills or are switching from the acid process to the alkaline at one mill.

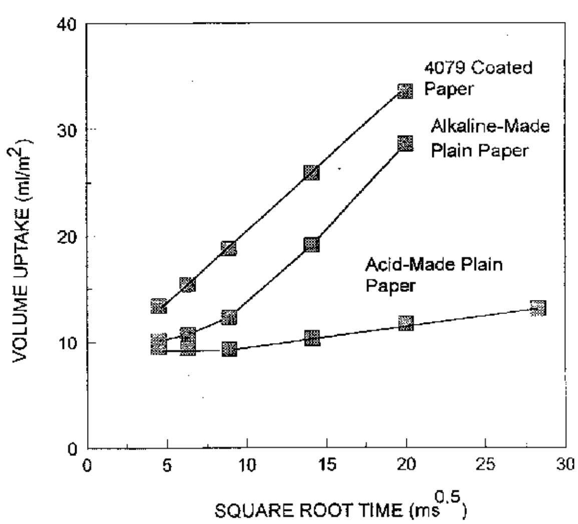

Figure 1. Penetration modes for alkaline- and acid-made papers compared to that for 4079 coated paper.

It is apparent that the alkaline-made paper better simulates the coated paper in the ability to sorb liquid at the longer time frames than the acid-made paper does. In fact, the volume uptake of the acid-made paper is quite limited and does not progress until after a sizeable wetting delay (about 100 msec). The penetration behavior during this time period is enhanced in Figure 2. The liquid uptake in the surface structure (volume uptake at 0 msec) is practically identical for the two plain papers. However, immediately after liquid-paper contact (<10 msec), the alkaline-made sheet provides penetration into the sheet structure. Moreover, assuming that this penetration is mainly of a capillary nature, it must be accompanied by expansion of the capillaries due to fiber swelling since liquid uptake increases more rapidly than a linear increase with square root time[3].

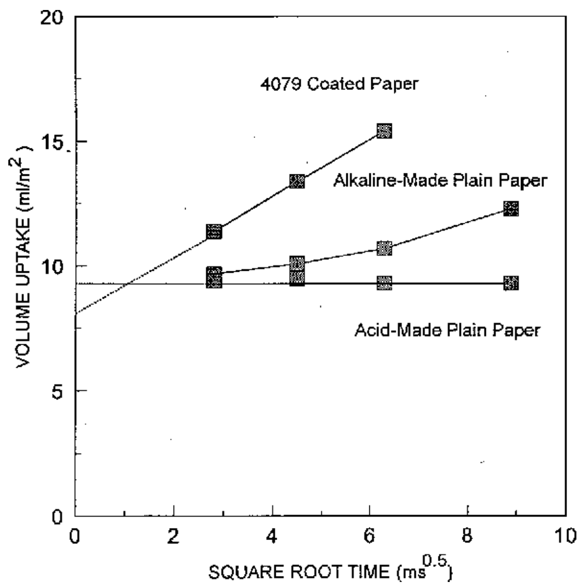

Figure 2. Short-time fiber swelling for alkaline-made paper compared to wetting delay for acid-made paper.

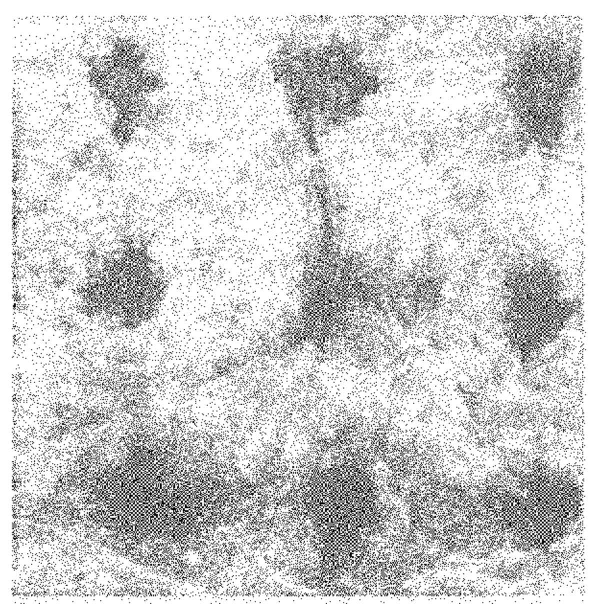

Figure 3. Dot definition for the alkaline-made paper.

The effect of short time swelling is readily noticeable in photomicrographs of ink jet printed dots using the 4079 printer (Figures 3 and 4). Dot fuzziness in the alkalinemade paper (Figure 3) is created by ink penetration into fiber cell walls and lumens immediately after ink-paper contact. Dot definition is much less dependent on fiber structure in the alkaline-made paper (Figure 4). This is due to wetting delay followed by non-swelling penetration.

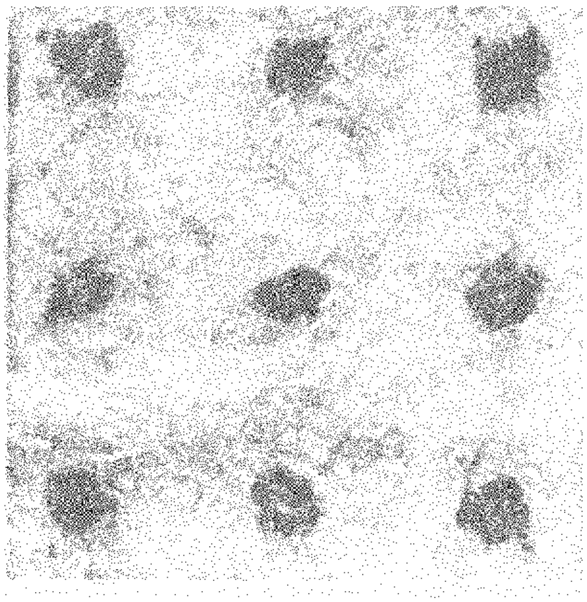

Figure 4. Dot definition for the acid-made paper

Paper Wettability

Static ink-paper interaction modes may be very different from dynamic ones such as in ink jet printing or in Bristow testing but are not necessarily unrelated as to the effect of paper variation in wettability[4]. Thus it was found that not only the two papers described above but a wide range of plain papers tested provided a great variation in print quality and in penetration modes when tested with large ink drops. This technique requires a drop size suitable for attaining the intermediate stages between "no penetration" and "complete penetration" shown in Figure 5[5]. Paper wettability, defined by "intrinsic contact angle" in the figure, determines to what degree "basal penetration" is obtained.

Using 0.004 ml drops of 4079 inks, it was found that stages 4-6 predominated for several of the alkaline-made xerograpic paper brands. Most acid-made xerographic papers showed no penetration (stage 2) even at time frames where the drops would evaporate completely. In reality, using drop testing in this way is a crude size testing procedure where the ink is used as the penetrating liquid. It then appears that as a group, alkaline xerographic papers are less (slacker) sized than acid xerographic papers.

Conclusions

Bares and Rennel[6] found that text print quality was optimized for liquid uptake rates less than 0.25 $ml/m^2ms^{0.5}$ using lower resolution printers (300 dpi). This is true for the acid-made paper in Figures 1 and 2. However, the present work suggests that text raggedness is due to fiber swelling immediately after ink paper contact rather than to a fast liquid uptake rate. In fact, a faster liquid uptake would be desirable in order to accommodate the larger ink amounts that are used for multi-color printing. A "best compromise" for the 4079 printer is a combination of the short time uptake for the acid-made paper and the longer time uptake for the alkaline-made sheet. This suggests that chemical surface modification of xerographic candidates in the alkaline-made paper group could be effective in modifying these for the ink jet application. At present, this happens to be an approach that has shown some success in instances where commodity xerographic paper brands have been improved for ink jet printing applications.

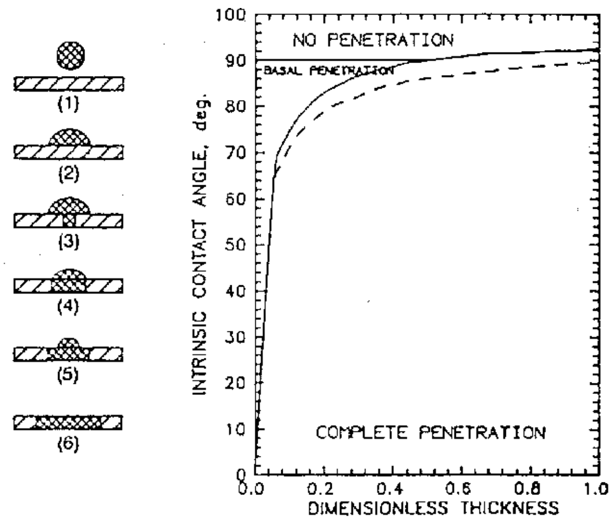

Figure 5. Theoretically calculated drop penetration modes for a thin porous medium simulating paper (Ref. 5)

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