Plain Paper Choices for Ink Jet Printing

J. Borch
Lexmark International, Boulder, Colorado

Abstract

A set of xerographic paper brands was analyzed for suitability in ink jet printing. This analysis included printing trials, liquid uptake measurements in the subsecond time frame, and image analysis of single drop definition. Though these papers were manufactured for copying and laser printing, several showed full color ink print characteristics equal to or better than plain paper brands designed for ink jet printing. Alkaline-made, synthetic-sized paper brands showed a wider variation in print quality than acid-made, rosin-sized paper brands. In general, for both paper types, a compromise is required between text and graphics print appearance (low liquid application) and full color print appearance (higher liquid application). This compromise appears to be mainly governed by fiber wettability which is affected by the internal and surface size treatments of the paper structure.

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Introduction

In a previous study[1,2] of office paper compatibility with ink jet printers, it was concluded that the ink penetration rate should not exceed a certain value (0.25 $ml/m^2 ms^{0.5}$) to provide adequate print appearance in letter quality text and graphics printing. Since then, ink jet printing in the office environment has evolved further, and full color printing, requiring larger ink volume applications with a fast ink uptake in the short time frame is becoming desirable[3,4]. At the same time plain office papermaking has changed from one with relatively little chemical variation from brand to brand (the acid-made, rosin-sized paper type) to one with various sizing additives used in more variable amounts (the alkaline-made, synthetic-sized paper type). That appears to have created a larger variability in ink jet print quality for the latter type[4].

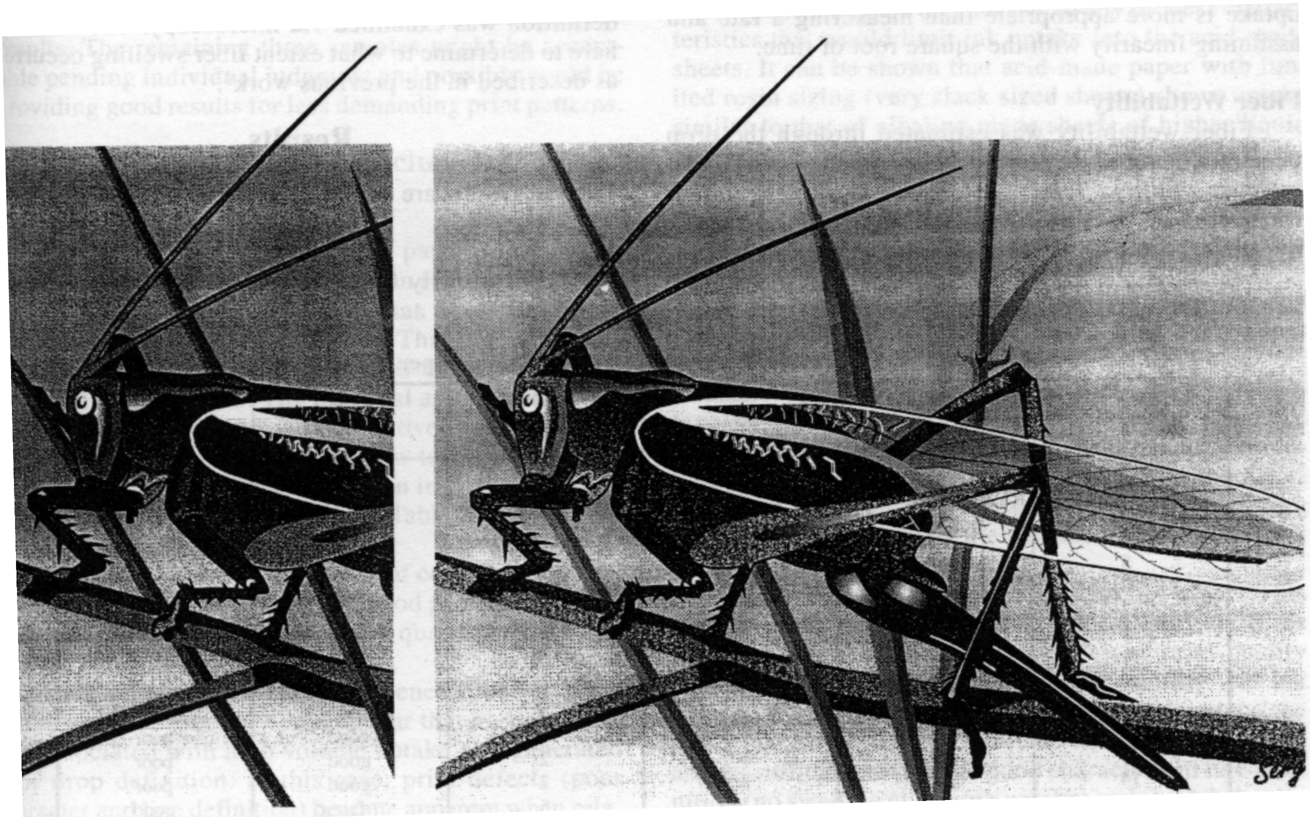

Figure 1. Increase in graininess for full color areas

The purpose of the present study is to characterize ink jet print quality in more detail for a set of xerographic paper brands widely used in the office environment at present. Though these papers were judged to be generally available as brand names in the U. S., they do not represent the entire xerographic grade paper market nor do they provide insight into print variation when the same brand is manufactured at different mill sites. The paper set included four brands specifically labelled for ink jet printing usage.

Experimental

Sample Printing

Full color printing of a CorelDRAW* sample (grashopp.cdr file) was carried out using an IBM Color Jet-printer 4079**. Print graininess in full color areas was compared as previously described for another CorelDRAW sample (3). The green areas of the grasshopper image were judged particularly suitable for such evaluation (Figure 1).

Dynamic Penetration

Dynamic penetration of 4079 ink in the 400 msec time frame was measured using a Bristow tester[3,4]. This provides a comparison of ink volume uptakes at that particular time. In contrast to Bares' work[1], where ink penetration rates increased linearly with the square root of time, several of our paper samples showed a faster increase with time[3,4]. Therefore, a comparison of volume uptake is more appropriate than measuring a rate and assuming linearity with the square root of time.

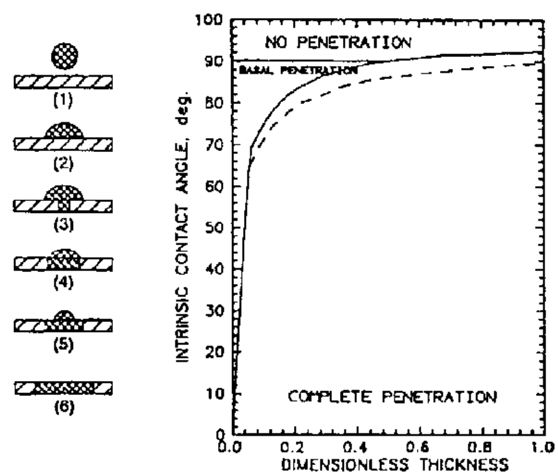

Figure 2. Theoretically calculated drop penetration modes for a thin porous medium simulating paper (Ref. 5)

Fiber Wettability

Fiber wettability was estimated through the drop penetration procedure previously described[4]. Using 0.004 ml drop volumes would determine a "dimensionless thickness" of 0.08 to 0.1 for the paper thicknesses in question (Figure 2). Pending on fiber wettability (intrinsic contact angle in Figure 2), this would provide no penetration, basal penetration or complete penetration for drops of the 4079 ink. The drop shapes were visually compared after one minute. The closest approximation to the following four conditions was determined: no penetration (2), limited basal penetration (4), extended basal penetration (5), and complete penetration (6) (Figure 2).

Single Drop Definition

Single drop printing was obtained for one of the 4079 printer's built-in test patterns (Test Print A). Single drop definition was examined via microscopy. The aim was here to determine to what extent fiber swelling occurred as described in the previous work[4].

Results

The test results are shown in Table 1.

Paper Analysis

As previously found (Papers 1 and 2 are the alkaline-made and acid-made plain papers previously described in Reference 4, there are huge differences in ink volume uptake when measured on the Bristow tester. All acid-made, rosin-sized papers showed limited uptake. Three alkaline-made, synthetic-sized paper (Papers I, 6, and 10) showed an uptake four to five times that of the acid-made samples and that of some of the alkaline-made samples. One alkaline-made paper (Paper 15) exhibited intermediate degree of liquid uptake.

The papers showed fiber wettability ranging from no penetration (Stage 2 in Figure 2) to complete penetration (Stage 6 in Figure 2). Papers 1,6, and 10 showed complete penetration. In general, papers with low liquid uptake showed no penetration (Stage 2 in Figure 2) to limited basal penetration (Stage 4 in Figure 2).

Papers 1, 6, 8, and 10 showed poor drop definition. Microscopy indicated that this was due to fiber swelling and ink penetration into fiber cell wall and lumens similar to that previously found for Paper I (4). However, most papers showed satisfactory drop definition, similar to that of Paper 2, and without the fuzziness that degrades character and line definition[4].

Sample Printing

It is realized that the graininess looked for in full color sample printing is just one aspect of plain paper usage for ink jet printing (see Paper Design Characteristics, in the following).

Nevertheless, this feature is very objectionable when using a printer that is capable of relatively high resolution output. Of the seventeen papers analyzed, only four papers provided good images. Ten papers showed poor results. The remaining three samples might be acceptable pending individual judgment and possibly could be providing good results for less demanding print patterns.

Discussion and Conclusions

Test Correlations

The liquid volume uptake for papers of different penetration characteristics is shown in Figure 3. This plot demonstrates the dominant role that fiber wettability plays in the liquid uptake process. This is of considerable interest from both a theoretical as well as from a practical point of view. The practical application is that

Table 1. Test results for seventeen xerographic paper brands.

Paper Brand	Process*	Volume uptake (ml/sqm)	Fiber wettability**	Drop definition	Print quality
1	alk	43	6	poor	good
2	acid	8.6	2	good	poor
3	alk	7.8	2	good	poor
4	acid	8.0	2	good	poor
5	alk	10.4	5	fair	fair
6	alk	33	6	poor	good
7	alk	8.0	2	good	poor
8	acid	9.6	5	poor	poor
9	acid	8.5	2	good	poor
10	alk	48	6	poor	good
11	alk	10.8	4	good	poor
12	acid	8.7	4	good	poor
13	acid	8.6	2	good	poor
14	acid	8.7	2	good	poor
15	alk	17	5	fair	good
16	alk	7.1	2	good	fair
17	alk	7.6	4	good	fair

*alk: alkaline-made, synthetic-sized; *acid: acid-made, rosin-sized; **see Figure 2 drop testing can be used as a qualitative paper screening process without the need for Bristow testing. This must be done for the exact ink formulation in question. Using different inks on the paper set in Table I changes the results obtained.

In the present study all papers of complete penetration (Papers I,6, and 10) showed good print quality. The only other sample of good print quality (Paper 15) showed extensive basal penetration.

Also, all papers of complete penetration provided poor drop definition. It would appear that high penetration associated with high volume uptake also generated poor drop definition. In this case, print defects (poor character and line definition) become apparent when relatively small ink amounts are employed.

This problem could be alleviated by choosing non-penetrating papers (Papers 2-4, 7, 9, 11-14, and 16-17). However, good print quality was not obtained. That is, the paper structure was not capable of the fast liquid uptake required to transfer large amount of inks from the paper surface.

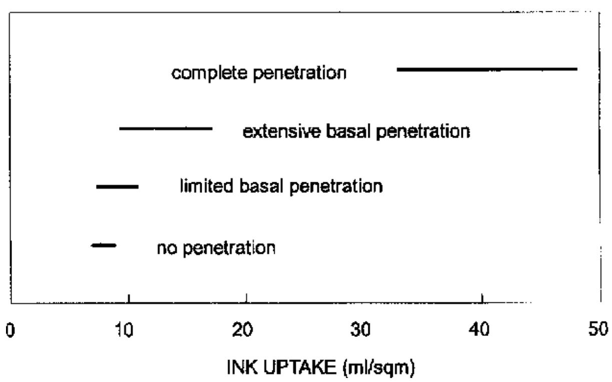

Figure 3. Liquid volume uptake for papers of different penetration characteristics

Paper Choice

Examination of the paper process (acid versus alkaline) in Table 1 would lead to the conclusion that acid-made, rosin-sized papers show limited ink uptake for no drop penetration whereas alkaline-made, synthetic-sized papers show a much wider range of uptake for the complete range of drop penetration. This is a result of the paper grade analyzed and not due to any process characteristics that would limit ink uptake into the acid-made sheets. It can be shown that acid-made paper with limited rosin sizing (very slack sized sheets) shows uptake similar to that of alkaline-made sheets of higher liquid uptake.

Nevertheless, this finding is important for choosing paper for full color printing. Since all acid-made papers in Table 1 showed mediocre print quality, the likelihood of finding acid-made paper brands of good print quality is low. In contrast, trade-offs between print quality and drop definition could be made for alkaline-made paper brands (see Papers 5 and 15-17).

The reason for this greater variation in print characteristics for alkaline-made paper is not quite clear. We believe that a greater variation in chemical size formulation for alkaline-made paper in addition to the desirability of using less of these more expensive sizing chemicals contribute to the greater variation in fiber wettability for alkaline-made paper.

Papers 14-17 were labelled for ink jet usage. This created good definition for fair print quality on three papers and fair drop definition and good print quality for one paper of intermediate fiber wettability and ink uptake. While we do not know what specific steps the paper makers have taken to create “ink jet usage”, they are not sufficient to provide good character and line definition (no swelling at low ink uptake) and good full color print for the same paper brand. For the papers of low ink uptake (Papers 14 and 16-17), print quality was enhanced beyond the poor level associated with other xerographic papers of low ink uptake, but good print quality was not obtained. Of all the papers tested, Paper 15 presents the best compromise for full color printing where little text and graphics are required.

Paper Design Characteristics

The present work emphasizes liquid uptake and the need for creating sufficient ink transfer into the paper structure to avoid the graininess associated with full color printing. However, other print characteristics, such as color saturation, show-through, and print cockle and curl, are adversely affected by high liquid uptake. All of the paper brands of fair to good print quality tested suffered from poorer color saturation and increased show-through when compared with coated papers manufactured for 4079 printer usage. At present, this printer and most other drop-on-demand (DOD) ink jet printers require a special coated sheet for optimum color printing.

The liquid uptake results obtained for the different paper samples show that there is a requirement for sufficient ink uptake necessary for full color printing and that this requirement is for relatively high liquid amounts. Plain papermaking imposes restrictions on the ink levels that can be transferred into the sheet structure during the subsecond time frame. Fiber wettability and the void structure inherent to the paper sheet dictate the amount of ink uptake possible. Sheet surface modifications are restricted to those that can be carried out for the plain paper grade and for full color printing appear only effective for those that will increase liquid uptake.

The xerographic paper grade imposes design characteristics defined by their usage in copiers and printers. The results obtained in the present work illustrate the desirability of adding additional characterization procedures if xerographic papers are intended for ink jet printing, also. A major obstacle is then to make these valid for different machine designs and ink formulations.

References

* CorelDRAW is a registered trademark of Corel Systems Corp.

** IBM is a registered trademark and Color Jetprinter is a trademark of International Business Machines Corporation in the U.S. and/or other countries and used under license.

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