A Comparison of Image Permanence and Print Durability Attributes for Commercial Digital Print Materials with Traditional Offset

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Abstract

High-speed inkjet and electrophotographic printing presses have recently made inroads into traditional commercial printing applications, such as direct mail, magazines, catalogs, and books. Each of these applications has similar but somewhat differing requirements and expectations for image permanence and print durability. In this study, we compare representative print samples produced by both digital and analog printing technologies for their image permanence and print durability performance. We will also discuss these results in the context of specific market applications.

Introduction

As digital printing technologies begin to approach the productivity and running costs of traditional printing presses, questions are being raised about how digital printing compares to offset in terms of the permanence and durability of the printed output, especially for commercial printing applications [1]. For the past fifty years, offset printing in its various embodiments has dominated the commercial printing markets. More recently, electrophotography (EP) and inkjet (IJ), also in various embodiments, have begun to penetrate certain segments of the commercial printing space, especially variable data applications such as transactional and "transpromo" printing. EP solutions have been implemented for applications such as trade books, self-published books, and photobooks, and now high-speed IJ presses from Eastman Kodak Company, IBM Infoprint, Dai Nippon Screen, Oce, Hewlett Packard, and others, are targeting these and other short-run commercial printing applications. As print quality and/or speed have continued to progress to higher and higher levels, other market segments, such as direct mail, books, magazines, and catalogs are being targeted.

Prints produced for each of these applications will likely experience different permanence and durability stress scenarios and will also be held to differing expectations for performance against these factors by both intermediate and end users.[1] By intermediate users, we mean anyone who touches or processes the printing article post-printing and prior to being delivered to the end user. This might include various types of post-processing and converting equipment, as well as shipping, distribution, as well as mail sorting and conveyance equipment.

In this paper, we conduct an initial survey of inkjet, electrophotographic, and offset printing technologies with respect to a number of permanence and durability factors, including environmental testing (light and ozone fastness), as well as physical durability testing, (smudge, abrasion, water, and highlighter resistance).

Materials and Methods

The results presented below were generated from two separate studies. In Part A, we examined the resistance of test targets, printed with the equipment and materials indicated in Table 1, to light and ozone. In Part B, we evaluated the physical durability (water resistance, dry smudge and abrasion resistance, and highlighter resistance) of test targets printed with the equipment and materials indicated in Table 2. Additional tests are in progress.

The offset lithographic (Goss Sunday 2000) and electrophotographic (Kodak NexPress SE3000 digital production color press) samples were printed by the Printing Applications Laboratory at the Rochester Institute of Technology. The inkjet samples were printed on engineering hardware configurations of a "Stream" continuous inkjet writing system [2] using a prototype CMYK aqueous pigmented ink set. Crossover testing with common inks and substrates indicate that the effect of hardware is very modest and should not affect the primary conclusions of this survey. Inkjet print samples were allowed to equilibrate under ambient conditions for at least 72 hours prior to testing. None of the samples used in this study were treated or over coated post-printing.

For light and ozone testing, we used a 6-step density tablet of the primary colors (CMYK), secondary colors (RGB), and process black (KP). Accelerated light fade testing was conducted at 23°C, 50% relative humidity (RH) using both 50 klux, glass-filtered xenon and 80 klux, polycarbonate-filtered, cool white fluorescent units [3]. Samples were read after 3, 7, 14, 28, and 56 days. Accelerated ozone fade testing was conducted at 23°C, 50% RH, and 1 ppmv of UV-generated ozone using an in-house built chamber [4]. Samples were read after 3, 7, 14, 28, and 56 days.

For water, smudge, and abrasion resistance, we printed 2-inch by 3-inch patches (40, 70, and 100% tints) of the primary colors (CMYK) and secondary colors (RGB, each surrounded by approximately 1 inch of unprinted paper. For dry smudge and abrasion testing we used a Sutherland rub tester equipped with a 4-lb weight, and Data Speed laser MOCR (International Paper) was used as the receptor (abrading surface) [5]. The test samples were positioned such that both the color patch and adjacent unprinted area were traversed by the weighted receptor, and the test was carried out for a total of 50 cycles (43 cycles/min). To assess water resistance, the test targets were treated as described in Method 2 (standing water plus wiping effects) of ISO 18935 [6].

Table 1: Ink and media combinations used for Part A of this study

System	Hardware	Inks/Toners	Paper
A-1	Goss Sunday 2000 Web Offset Press	Sun Chemical Sunultra Universal Process Inks	NewPage Sterling Ultra Gloss
A-2	Kodak NexPress SE3000 press	Kodak NexPress Enhanced Dry Inks	NewPage Sterling Ultra Digital
A-3	Stream CIJ 4-color test stand	Kodak Prosper Pigmented Inks (prototype)	NewPage Sterling Ultra Gloss (surface treated)*

*Coated with ca. 0.5 g/m^2 of a mixture of polymer binder and calcium chloride [7].

Table 2: Ink and media combinations used for Part B of this study

System	Hardware	Inks/Toners	Paper
B-1	Goss Sunday 2000 Web Offset Press	Sun Chemical Sunultra Universal Process Inks	NewPage Sterling Ultra Gloss
B-2	Goss Sunday 2000 Web Offset Press	Sun Chemical Sunultra Universal Process Inks	International Paper Data Speed Laser MOCR
B-3	Kodak NexPress SE3000 press	Kodak NexPress Enhanced Dry Inks	NewPage Sterling Ultra Digital
B-4	Kodak NexPress SE3000 press	Kodak NexPress Enhanced Dry Inks	International Paper Data Speed Laser MOCR
B-5	Kodak Prosper Press (prototype)	Kodak Prosper Pigmented Inks (prototype)	NewPage Sterling Ultra Gloss (surface treated)*
B-6	Kodak Prosper Press (prototype)	Kodak Prosper Pigmented Inks (prototype)	International Paper Data Speed with ImageLok

*Coated with ca. 0.5 g/m^2 of a mixture of polymer binder and calcium chloride [7].

Status T densitometry and CIElab colorimetry (Gretag-Macbeth Spectrolino) were monitored at the indicated intervals for each of the tests, and the changes in density and colorimetry relative to those measured for an untreated sample were calculated. No corrections were made for D-min. For the water resistance and dry abrasion testing, the transfer of color from a 100% tint to the adjacent unprinted area ("smudge") was also measured. The general conclusions of this study are the same independent of the use of densitometry or colorimetry to monitor changes to the test targets; therefore, only densitometric data are presented.

Highlighter resistance was tested on a line of 8 point black text using a Papermate "Intro" yellow highlighter (Sanford LP, USA). Only black text was evaluated for this test. The highlighted text was subjectively rated after one, two, and three successive strokes of the highlighter over a line of text using the following scale:

No visible change 1
Just noticeable smearing of text 2
Significant smearing of text 3
Heavy/unacceptable smearing of text 4

Results and Discussion

Image Quality and Image Durability

Before we discuss the response of the different printing systems to the various stress factors that can impact the permanence and durability of a printed piece, it important to understand the condition of the print prior to stressing it (t = 0 condition). In a general sense, the initial condition of the print is characterized by a variety of attributes, e.g., color reproduction, tone scale, contrast, resolution, sharpness, etc., that, taken together, define the image quality of the printed output. Depending upon the nature of a given stress factor, one or more of the various attributes that make up the overall image or print quality may be affected.

Image durability can be defined as the change or degradation of the initial image quality over time in response to a wide array of stress factors. One way to think about image durability is to differentiate between those factors that affect the image permanence from those that impact print durability. Although this may seem like a subtle or semantic distinction, it becomes clearer when one thinks of image permanence factors as being primarily environmental factors, e.g., light, heat, air pollutants, and humidity, and print durability factors as being physical factors. Environmental stresses are constantly and cumulatively acting on the print over its useful life. Physical stresses are more likely to be caused by specific, often one-off interactions of the print with humans, machines, or the forces of nature. Physical stresses can include the intentional or accidental interaction of the print with water or other fluids, subjecting the print to mechanical forces such as friction, tension, flexure, etc., or combinations of the above.

Many physical stresses are encountered between the time the actual print or image is generated and when it is delivered to the end-user. For example, a mail solicitation piece may be subjected to friction, tension, and flexure as the printed web is transported through the converting equipment, slit, chopped, folded, and inserted into an envelope, and then transported through various pieces of equipment used by the postal system to convey and sort the mail, and, finally during the delivery of the mail, it may be subjected to water in the form or rain, sleet, or snow. Another example of a combination of physical stresses is the application of a highlighter to a trade book or text book, wherein both fluid and friction are simultaneously applied to the printed page.

Image Permanence Performance

The results for the accelerated light and ozone fade testing are summarized in Tables 3–5. The glass-filtered xenon test condition most closely approximates window-filtered daylight, a condition that predominates the typical home or apartment [8]. On the other hand, the filtered fluorescent test condition more closely simulates an office or indoor commercial environment. Although ambient ozone levels can vary greatly as a function of time of day, season, and type of HVAC system (indoor), the test condition of 1 ppmv is approximately 10–100 times more concentrated than ambient levels [4,8].

A quick glance at the light fade data shows that yellow is the weakest colorant independent of printing technology. Offset is significantly more sensitive to the light fade test condition than either EP or IJ. The results for offset are actually worse than the data imply: under both illumination conditions the offset samples were badly faded after only 7 days of treatment. Interestingly, the IJ system is worse than the EP system under xenon illumination, but under fluorescent illumination, the results are reversed. For most commercial printing applications, both the EP and IJ prints should perform quite well with respect to typical product-intent levels of light and ozone exposure.

Table 3: Results for 50 klux, glass-filtered xenon light fade testing, 28 days

System	%ΔD (from 1.0)	Worst color
A-1	–88	yellow
A-2	–19	yellow
A-3	–33	yellow

Table 4: Results for 80 klux, polycarbonate-filtered fluorescent light fade testing, 28 days

System	%ΔD (from 1.0)	Worst color
A-1	>–90	yellow
A-2	–25	yellow
A-3	–9	yellow

Table 5: Results for 1 ppmv, ozone fade testing, 56 days

System	%ΔD (from 1.0)	Worst color
A-1	–4	yellow
A-2	<1	N/A
A-3	–12	magenta, cyan

Ozone resistance is very good for all three systems, with the EP exhibiting negligible fade for any of the colors. Offset was slightly worse, with yellow again the weakest colorant. The IJ system was interesting in that the fade rates for the cyan, magenta, and yellow colorants were nearly the same, producing an almost neutral fade, which is less noticeable than when the fade rates of each of the primary colors are much different. Overall, the ozone resistance of all three systems should meet most user expectations for commercial printing applications.

High temperature and high humidity testing of these systems are currently in progress. Based upon a preliminary examination of the data, all three systems are expected to perform well in these tests.

Print Durability Performance

The results for the dry smudge and abrasion resistance, water resistance, and highlighter resistance are summarized in Tables 6–8. Dry abrasion and smudge resistance is an important attribute for most commercial print applications. Not only is it expected from the end user, it is also required in order to endure the post-printing processes (rewinding, sheeting, folding, binding, etc.) as well as the shipping and handling of the printed piece to the final customer. Perhaps one of the most demanding applications with respect to smudge and abrasion resistance is direct mail [9].

The dry smudge and abrasion test was originally run for just 10 cycles, but there was very little measureable change for any of the samples. A separate sample was then treated for 50 cycles, and the results are shown in Table 6. With respect to samples printed on the coated glossy papers (B-1, B-3, and B-5), the offset-printed samples fared the best, followed by IJ and EP. Interestingly, the offset sample actually showed an 8% increase in density for the 40% tint. This can be explained if the individual dots are smeared slightly, effectively increasing their size and consequently the measured density. However, the smudge data would suggest that any smearing must be very localized. For the uncoated bond papers (B-2, B-4, and B-6), there is not as much of a difference between the printing systems, although both IJ and EP appear to show a higher degree of smudge (ΔD-min) on these papers. Both IJ and EP perform poorer on the coated glossy paper than on the uncoated bond paper, but this trend was reversed for the offset samples.

Table 6: Results for dry smudge and abrasion resistance testing

System	%ΔD (100% tint)	Worst color	%ΔD (40% tint)	Worst color	ΔDmin (smudge)	Worst color
B-1	–4	C	+8	K	+0.01	C,M
B-2	–11	C	–9	K	+0.01	K
B-3	–39	B	–24	Y	+0.02	R
B-4	–21	K	–9	B	+0.08	Y
B-5	–21	B	–7	B	+0.03	C,B
B-6	–10	K	–3	C	+0.07	C,K

ISO 18935, originally developed to evaluate the water resistance of both digital and analog photographic imaging materials, describes three different water resistance test methods. Method 1 (“standing water evaporation”) simulates the effect of water spilled on an image and simply left to dry. Method 2 (“standing water plus wiping effects”) introduces a mechanical stress to the procedure by pulling a weighted (50 g) laboratory tissue across the moistened sample. In Method 3 (“water soak”), the sample is completely immersed in water for 1 hour, then allowed to air dry, simulating a more catastrophic event, such as a flood. For each method, the standard prescribes a qualitative visual assessment of a specified test pattern relative to an untreated control in order to categorize the results. For the purposes of our study, we felt that Method 2 would produce the most relevant results. In order to quantify and more easily compare the responses, we used the same target and measurement technique as described above for the dry smudge and abrasion test.

The water resistance results for Method 2 measured by densitometry are summarized in Table 7. When the results for the 100% tint test patterns are compared, the EP samples perform the best, followed by offset, and then IJ. However, for the 40% tint patterns and for D-min smudge, the differences are much less pronounced. Interestingly, the IJ sample on uncoated bond paper (B-6) shows slightly more smudge than the other samples, with the black ink being the most noticeable. This sample was also the only one that showed any signal for the highlighter resistance test, which is essentially another type of wet smudge and abrasion assessment.

Highlighter resistance is most relevant to book printing applications, especially text books. The Papermate "Intro" highlighter was chosen for this test based on an initial screening study involving over a dozen different commercially available highlighter brands and styles. This particular highlighter was generally more aggressive than the others that we screened. However, for the samples included in this study, all held up quite well. Only the IJ sample on uncoated bond paper (B-6) shows slight evidence of smearing of the text after 3 successive strokes.

Table 7: Results for water resistance testing

System	%ΔD (100% tint)	Worst color	%ΔD (40% tint)	Worst color	ΔDmin (smudge)	Worst color
B-1	–14	G	–2	B	+0,01	M,G
B-2	–11	M	–9	M,B	+0.01	R
B-3	–4	M	–4	Y	+0.01	R
B-4	–7	C,M	–15	C	+0.01	K
B-5	–9	G	–4	G	<0.01	N/A
B-6	–17	R	–7	R	+0.04	K

Table 8: Results for highlighter resistance testing

System	1 stroke	2 strokes	3 strokes
B-1	1	1	1
B-2	1	1	1
B-3	1	1	1
B-4	1	1	1
B-5	1	1	1
B-6	1	1	2

Summary and Conclusions

Table 9 attempts to summarize the relative performance of the offset, EP, and IJ printing systems included in this study against the various permanence and durability stress factors. For the purpose of this comparison, we have defined offset as the reference or "datum," and qualitatively assessed the EP and IJ systems using the following scale:

++	significantly better than offset
+	slightly better than offset
O	comparable to offset
–	slightly worse than offset
--	significantly worse than offset

It should be stressed that this study represents an initial survey of the permanence and durability of commercial print samples, and the combinations of hardware, inks, and substrates chosen for this study are not necessarily representative of each printing technology across the board. Furthermore, for any given commercial printing application, the relative importance of the various stress will likely change, either due to different degrees of user expectations and/or the probability of encountering a given stress factor at a level sufficient to cause noticeable damage. Nevertheless, these results suggest that for many commercial printing applications, both EP and IJ approach, and in some cases exceed, the performance of traditional offset. For some of the more physically demanding applications where dry abrasion is more important, such as direct mail, an over coat or varnish may be required, but this is commonly practiced today, even for offset printed pieces [9].

Table 9: Summary of results

	Offset	EP	IJ
Light	Datum	++	++
Ozone		O	O
Heat		In progress	
Humidity		In progress	
Dry smudge		–	–
Dry abrasion		–	–
Wet wipe		O	O
Wet soak		O	O
Highlighter		O	O

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