The Determination of the Minimum Force to Initiate Abrasion Damage of Digital Press Prints

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Abstract

The purpose of the project was to determine the minimum levels of force and abrasion cycles necessary to produce a just noticeable difference (JND) in objects printed with modern digital presses (documents, book pages, etc.). The results of this work are intended to help cultural heritage institutions that collect these materials develop policies for use and care to prevent damage to their collections. The results may also benefit commercial services that offer prints made with these processes or manufacturers of the equipment or media.

A variety of digital press technologies and papers were studied. Specimens were abraded using the Sutherland 2000 Rub Tester with both ¼-lb and 2-lb loads. The lighter weight was an attempt to replicate physical handling of materials such as page turning in books or sorting sheets in stacks of documents. The use of the heavier weight was an attempt to emulate unbound prints being pulled from larger stacks as well as unbound prints in stacks during transport. The abrading surfaces included unprinted and printed sheets to replicate single-sided prints in stacks or double-sided prints in stacks or books. A series of abrasion cycles were produced for each of the materials to determine when JND could be observed. Visual observations were correlated to average grey values to determine if a quantifiable threshold limit for this property was possible. Additionally, the relative sensitivity of the various materials to abrasion was compared. The tests included measuring colorant smear from a black printed area to an adjacent white area, loss of colorant from the black area, and transfer of colorant to an adjacent sheet. The change in average gray levels were measured with image analysis software for both the black patches and adjacent unprinted areas before and after abrasion as well as the transfer of colorant from printed faces to adjacent unprinted papers. Also gloss measurements before and after were used to determine the extent of gloss change in the black patches.

The results show that the major factors influencing the extent of damage from abrasion are the printing technology and the printed paper. From previous work it was known that smear of colorant is more objectionable than gloss change. However, with some digital press/paper combinations noticeable gloss change can be seen before noticeable smear of colorant. While not as severe as smear, change in gloss, especially when it is uneven, is still of concern to museum, library, and archive personnel and patrons. Results from the use of the lighter abrasion weight to simulate the turning of pages or sorting of sheets in stacks indicated that this should not be a problem no matter which printing technology or paper is used as no noticeable damage was observed either by measurement or visual assessment even after many hundreds of abrasion cycles. The heavier weight showed differentiation of the sensitivity of the different printer technology/paper combinations indicating a greater concern is needed for objects that may be inadvertently subjected to higher forces, especially with digital press inkjet technology.

Introduction

The purpose of the project was to determine the minimum levels of force and abrasion cycles necessary to produce a just noticeable difference (JND) in digital press printed materials. Visual observations were correlated to image analysis techniques to determine if a quantifiable threshold limit for this property was possible. Finding the JND is critical to establishing best practices institutions need in order to prevent noticeable damage to their collection assets. Additionally, the relative sensitivity of the various digital press technologies and printing papers to abrasion was determined.

In earlier investigations, the Image Permanence Institute (IPI) developed test methods to evaluate the resistance of digitally printed materials to abrasion [1]. These methods were used to rank the resistance of different types of digital prints to abrasion [2]. The results obtained gave collection caretakers a sense of which materials could be problematic but not how much handling would actually lead to noticeable damage. Other investigations on abrasion have been reported for photographic film [3,4] and only limited work has been published for other types of digital reflection images [5,6,7].

Sample Selection

Three digital press technologies were evaluated along with an offset lithography benchmark for comparison purposes. Three of the same papers (uncoated, coated and recycled) were printed by each of these technologies except in the case of the inkjet digital press. In this case a different paper (inkjet coated) was printed. Sample identification for each of these printer/paper combinations and abrader conditions are provided in Table 1. The identifiers "C" and "F" refer to the use of the printed side as the abrader for the unprinted back side. The identifiers "CV" and "FV" refer to the use of the unprinted print back as the abrader for the printed black patch target. These sample identifications are used in Figures 3 and 4 in this paper.

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Table 1: Sample identifications for the printer/paper combination and the abrader conditions used in this investigation.

Abrader: Printed Side, Abrader Weight: 2-lb

	Dry Toner	Liquid Toner	Offset	Inkjet
Paper A (Uncoated)	11aC	12aC	14aC	-
Paper B (Coated)	11bC	12bC	14bC	-
Paper C (Coated recycled	11cC	12cC	14cC	-
Paper D (Inkjet coated)	-	-	-	13C

Abrader: Unprinted Sid Abrader Weight: 2-lb

	Dry Toner	Liquid Toner	Offset	Inkjet
Paper A (Uncoated)	11aCV	12aCV	14aCV	-
Paper B (Coated)	11bCV	12bCV	14bCV	-
Paper C (Coated recycled)	11cCV	12cCV	14cCV	-
Paper D (Inkjet coated)	-	-	-	13CV

Abrader: Printed Side, Abrader Weight: 1/4-lb

	Dry Toner	Liquid Toner	Offset	Inkjet
Paper A (Uncoated)	11aF	12aF	14aF	-
Paper B (Coated)	11bF	12bF	14bF	-
Paper C (Coated recycled	11cF	12cF	14cF	-
Paper D (Inkjet coated)	-	-	-	13F

Abrader: Unprinted Sid Abrader Weight: 1/4-lb

	Dry Toner	Liquid Toner	Offset	Inkjet
Paper A (Uncoated)	11aFV	12aFV	14aFV	-
Paper B (Coated)	11bFV	12bFV	14bFV	-
Paper C (Coated recycled)	11cFV	12cFV	14cFV	-
Paper D (Inkjet coated)	-	-	-	13FV

Sample Preparation, Test Procedure and Measurements

All printed test samples were conditioned for a minimum of one week at 21±2 °C, 50±5 %RH to allow both adequate dry-down time and moisture conditioning. All testing was done at these temperature and humidity conditions. Three replicates of each material type were abraded and the averages reported. Specimens were abraded using the Sutherland® 2000 Rub Tester with both ¼-lb and a 2-lb loads at 85 cycles per minute in order to minimize the abrasion time.

The lighter weight was an attempt to replicate the physical handling of materials such as turning pages in bound volumes. The use of the heavier weight emulates unbound prints being pulled from larger stacks as well as unbound prints in stacks during transport. A series of abrasion cycles were produced for each of the materials to determine when a just noticeable difference (JND) could be observed next to black patch targets for prints abraded with print backs or the transfer of face-printed material to adjacent unprinted paper backs. The series of abrasion cycles included 1000, 500, 100 but with some samples 50, 25, 10, 5, and even one cycle was used because dark smear and/or gloss change was observed with very few cycles. The abraders included unprinted print backs and printed print faces.

Specimens contained a patch printed to a uniform maximum black density (RGB 0,0,0). An adjacent unprinted area was included to determine the degree of smear from the black area. The change in average gray level was measured utilizing ImageXpert® software and hardware for both the black patches and the adjacent unprinted white areas before and after abrasion as well as the transfer of printed colorant from print faces to adjacent unprinted paper. The average gray level values are from 0 to 255, where 0 is dark and 255 is light. An example of the black patch test target and the ImageXpert® ROI (regions of interest) after some abrasion are shown in Figure 1. An example of color print face used to abrade the unprinted print back is shown in Figure 2.

Gloss measurements were used to determine the extent of damage in the black patches. Gloss damage was measured using a BYK Gardner Glossmeter, which determines gloss at angles of 20°, 60°, and 85°. The optimum angle depends upon the original gloss of the specimen. Highly reflective surfaces are best measured at 20°, semi-gloss surfaces at 60°, and matte surfaces at 85°. The appropriate gloss angle was used, depending on the characteristics of the unabraded black patch specimen. Gloss measurements were not made in the unprinted areas outside of the black patches.

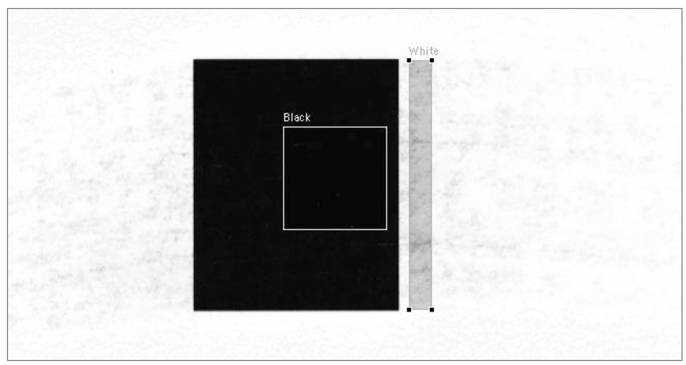

Figure 1: *An example of the black patch test target after some abrasion and ImageXpert® regions of interest.*

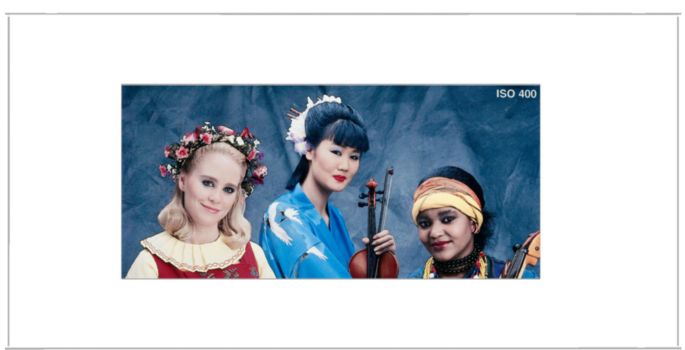

Figure 2: *An example of color print face used to abrade the unprinted print back.*

Table 2: Printer/paper combinations and abrasion conditions for dark smear JND.

Dark Smear JND

Abrader: Printed Side, Abrader Weight: 2-lb

	Dry Toner	Liquid Toner	Offset	Inkjet
Paper A	None	None	50	-
Paper B	None	1000	500	-
Paper C	None	1000	500	-
Paper D	-	-	-	1

Abrader: Unprinted Side, Abrader Weight: 2-lb

	Dry Toner	Liquid Toner	Offset	Inkjet
Paper A	None	1000	25	-
Paper B	500	None	25	-
Paper C	500	500	10	-
Paper D	-	-	-	None

Abrader: Printed Side, Abrader Weight: 1/4-lb

	Dry Toner	Liquid Toner	Offset	Inkjet
Paper A	None	None	None	-
Paper B	None	None	None	-
Paper C	None	None	None	-
Paper D	-	-	-	None

Abrader: Unprinted Side, Abrader Weight: 1/4-lb

	Dry Toner	Liquid Toner	Offset	Inkjet
Paper A	None	None	None	-
Paper B	None	None	None	-
Paper C	None	None	None	-
Paper D	-	-	-	None

Table 3: Average gray value differences for printer/paper combinations and abrasion conditions for dark smear JND.

Dark Smear JND

Abrader: Printed Side, Abrader Weight: 2-lb

	Dry Toner	Liquid Toner	Offset	Inkjet
Paper A	None	None	(50) **6.83**	-
Paper B	None	(1000) **3.53**	(500) **1.97**	-
Paper C	None	(1000) **2.13**	(500) **3.20**	-
Paper D	-	-	-	(1) **3.82**

Abrader: Unprinted Side, Abrader Weight: 2-lb

	Dry Toner	Liquid Toner	Offset	Inkjet
Paper A	None	(1000) **1.48**	(25) **4.24**	-
Paper B	(500) **2.44**	None	(25) **1.18**	-
Paper C	(500) **3.36**	(500) **1.69**	(10) **1.00**	-
Paper D	-	-	-	None

Abrader: Printed Side, Abrader Weight: 1/4-lb

	Dry Toner	Liquid Toner	Offset	Inkjet
Paper A	None	None	None	-
Paper B	None	None	None	-
Paper C	None	None	None	-
Paper D	-	-	-	None

Abrader: Unprinted Side, Abrader Weight: 1/4-lb

	Dry Toner	Liquid Toner	Offset	Inkjet
Paper A	None	None	None	-
Paper B	None	None	None	-
Paper C	None	None	None	-
Paper D	-	-	-	None

Table 4: Average gray value differences for printer/paper combinations and abrasion conditions for dark smear JND.

Gloss JND

Abrader: Printed Side, Abrader Weight: 2-lb

	Dry Toner	Liquid Toner	Offset	Inkjet
Paper A	None	None	None	-
Paper B	100	None	25	-
Paper C	100	1000	500	-
Paper D	-	-	-	500

Abrader: Unprinted Side, Abrader Weight: 2-lb

	Dry Toner	Liquid Toner	Offset	Inkjet
Paper A	1000	None	None	-
Paper B	100	1000	25	-
Paper C	100	500	500	-
Paper D	-	-	-	500

Abrader: Printed Side, Abrader Weight: 1/4-lb

	Dry Toner	Liquid Toner	Offset	Inkjet
Paper A	None	None	None	-
Paper B	1000	None	500	-
Paper C	1000	1000	1000	-
Paper D	-	-	-	None

Abrader: Unprinted Side, Abrader Weight: 1/4-lb

	Dry Toner	Liquid Toner	Offset	Inkjet
Paper A	None	None	None	-
Paper B	None	None	500	-
Paper C	None	None	1000	-
Paper D	-	-	-	1000

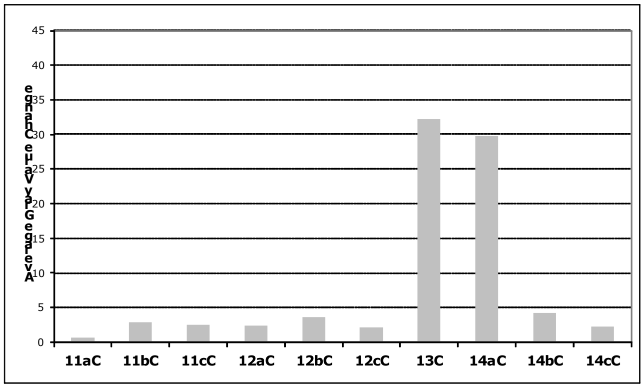

Figure 3: Average gray value change due to colorant transfer onto print backs when the printed front is used as the abrader for the various printer/paper combinations. This comparison is under the most severe conditions tested (2-lb/1000 cycles).

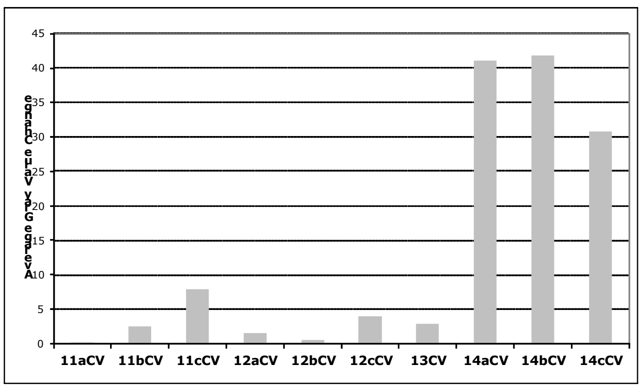

Figure 4: Average gray value change in the white area adjacent to black patches when the print back is used as the abrader for the various printer/paper combinations. This comparison is under the most severe conditions tested (2-lb/1000 cycles).

Results and Discussion

Table 2 (for dark smear) and Table 4 (for gloss) show the fewest number of abrasion cycles that produced a just noticeable difference (JND) from visual observation. In these situations, fewer cycles showed no noticeable difference from an unabraded sample. When the greatest number of abrasion cycles (1000) did not produce a noticeable difference, the word "None" is indicated for that printer/paper combination and abrasion condition. Table 3 shows the ImageXpert® gray value differences for the number of abrasion cycles that produced a JND. That number of cycles is the number in parenthesis in the table. The data for dark smear in Table 3 show that the offset digital press prints were more prone to abrasion that the other technologies with the exception of the inkjet digital press, which appears to be extremely sensitive to abrasion when abraded with the printed side. Even with one cycle, noticeable smear occurred on the unprinted side of the paper. It is also interesting to note that smear from the black patch into the adjacent white area for this printer/paper combination does not appear to be a problem when abraded with the unprinted side.

Comparison data are given in Figures 3 and 4 for the average gray value changes that occur in the various digital press technologies when abraded with printed paper fronts and unprinted paper with a 2-lb weight and 1000 cycles. No data are given here for average gray value changes with the ¼-lb weight because the values are all less than one. It appears from the data that gray value differences from unabraded samples in the range of about one to seven correspond to JND for dark smear.

Glossmeter data from the black patches could not be used to correlate with visual observations because in most cases the visual observation was more obvious in the unprinted areas of the samples, which was not measured, rather than in the black patches. It is clear from the data in these tables that JNDs for gloss can occur with fewer abrasion cycles than produce JNDs for dark smear.

Conclusions and Recommendations

1. Results from the use of the ¼-lb abrasion weight to simulate the turning of pages in photobooks indicated that this should not be a problem no matter which printing technology or paper is used as no noticeable damage was observed either by measurement or visual assessment even after many hundreds of abrasion cycles.
2. Based on the results with the 2-lb weight with a single inkjet digital press and a single type of paper, the use of
3. this technology for anything other than photobooks could be problematic. At this point concern exists for materials printed with this technology. Further evaluations with other inkjet digital presses and/or papers needs to be done to determine if there is a general problem with this technology or if this is unique to this printer/paper combination.
4. Offset technology is generally more sensitive than electrophotographic (EP) technology with respect to abrasion, therefore existing care practices for offset would be adequate for EP.
5. With some digital press/paper combinations noticeable gloss change can be seen before smear of colorant is evident. While not as objectionable as colorant smear, change in gloss, especially if uneven, is still a concern.
6. In this work, gray value differences in the range of about one to seven correspond to JND for dark smear. It might be possible to "fine tune" this range if intermediate abrasion cycles between those selected for this study were tried. Obviously further work needs to be done to identify a quantifiable limit for abrasion.

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Author Biography

Gene Salesin, Research Assistant, received a B.S. in chemical engineering from the University of Michigan and an M.S. and Ph.D. in chemistry from Case Western Reserve University in 1960 and 1962, respectively. He retired in 1997 after 36 years of employment in the research laboratories and several manufacturing divisions at Kodak. He held a management position during his last few years there, leading the staff involved with providing the technical instructions and specifications for the manufacture of black-and-white films. Dr. Salesin joined IPI in 2004 and has been involved in the permanence properties of magnetic tape and digital prints. He has co-authored seven papers on the permanence properties of digital prints since 2007.