The Determination of the Minimum Force to Initiate Abrasion Damage of Digitally Printed Documents and Photographs

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Abstract

The purpose of the project was to determine the minimum levels of force and number of abrasion cycles necessary to produce a just noticeable difference (JND) in documents and photographs printed with digital technologies. 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, manufacturers of the printers and media used to produce these materials as well as artists and photographers.

A variety of digital printers 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 these materials such as sorting sheets in small stacks or sliding prints in and out of enclosures. The use of the heavier weight was an attempt to emulate documents and photographs being pulled from large stacks as well as the possible damage to materials in stacks during transport. The abrading surfaces included unprinted paper backs to simulate prints in stacks, storage envelope papers and clear polyester sheets to simulate individual prints in enclosures.

A series of abrasion cycles were produced for each of the materials to determine when JND could be observed. Visual observations were correlated with image analysis data to determine if a quantifiable threshold limit for this property was possible. Additionally, the relative sensitivity of the various materials to abrasion was also explored.

The tests included measuring smearing of colorant from a printed area to an adjacent white area as well as the resulting loss of colorant from the black area. The changes in average gray levels were measured with image analysis software for both the black patches and adjacent unprinted areas before and after abrasion. Also gloss measurements before and after were used to determine the extent of gloss change in the black patches of photographs.

The results show that the major factors influencing the extent of damage from abrasion are the printer/paper technology and the smoothness of the abrader. Transfer of colorant from printed areas to the adjacent white unprinted areas is quite noticeable in some cases. From previous work it was known that this smear of colorant is more objectionable than gloss change. However, with some digital printer/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, archive personnel as well as artists and photographers.

Results from the use of the lighter abrasion weight to simulate sorting of sheets in small stacks indicated that this or the use of polyester or envelope paper enclosures should not be a problem no matter which printing technology or abrader is used as no noticeable damage was observed either by measurement or visual assessment. The heavier abrasion 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. Also the results of this study reinforce the results of previous work that polyester is a good choice for enclosures in direct contact with the surface of prints.

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 digitally printed documents and photographs. 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 these materials such as sorting sheets in small stacks or sliding prints in and out of enclosures. The use of the heavier weight was an attempt to emulate documents and photographs being pulled from large stacks as well as the possible damage to materials in stacks during transport. The abrading surfaces included unprinted paper backs, storage envelope papers and polyester sheets. 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 digitally printed documents and photographs 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 some work has been published for other types of digital reflection images [5,6,7,8]. Additionally, some work has been done comparing the scratch sensitivity of digital reflection prints to their abrasion sensitivity [9].

Sample Selection

For photographs, five different printers were selected for printing on five different photo papers which represented three different digital print technologies: dye diffusion thermal transfer (D2T2), inkjet (IJ) pigment and IJ dye. A chromogenic sample was included to serve as a benchmark technology. For documents, seven different printers were selected for printing two different plain document papers which represented four different digital print technologies: black and white electrophotographic (EP), color EP, IJ pigment and IJ cyan, magenta and yellow dye with black pigment (referred to as IJ hybrid in this paper).

Sample Preparation, Test Procedure and Measurements

All of the document samples were printed with three test targets: the black patch, pictorial and the text target. The photograph samples were printed only with the black patch and pictorial targets. Examples of the targets are shown in Figure 1. 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. A series of abrasion cycles were produced for each of the materials to determine when a JND could be observed for any of the three targets with any of the abrading materials. The series of abrasion cycles included 1000, 500, 100, 50, 25, 10, 5 for documents and 100, 50, 25, 10, 5, 1 for photographs. The abraders included unprinted paper backs, envelope paper and polyester sheets.

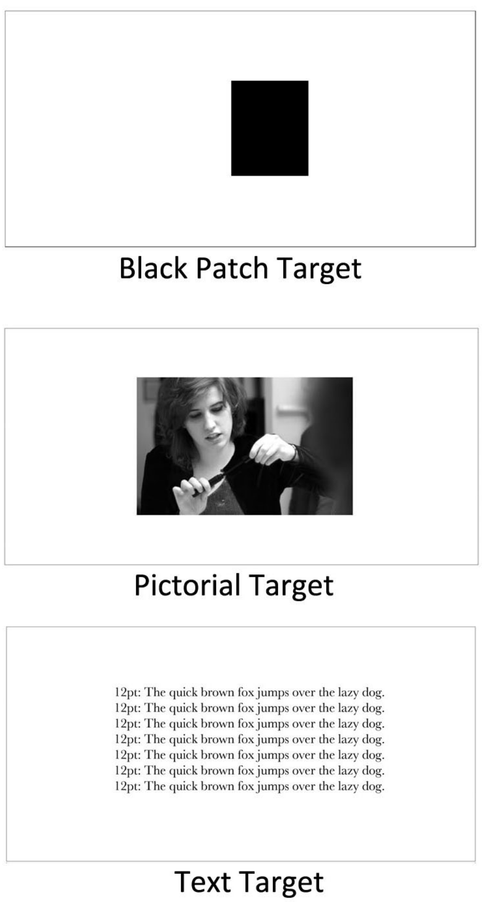

Figure 1: *Examples of the three test targets used in this investigation.*

The black patch target was printed to a uniform maximum black density (RGB 0,0,0). An adjacent unprinted area (or white patch) 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. The average gray level values are from 0 to 255, where 0 is dark and 255 is light.

Gloss measurements were used to determine the extent of damage in the black patches for photographs. 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 for documents or in the unprinted areas outside of the black patches in photographs.

Results and Discussion - Photographs

Tables 1 and 2 for dark smear and gloss with a 2-lb abrasion weight for both envelope paper and paper back abraders show the number of abrasion cycles that produced a JND for photographs using visual observation. In these situations, fewer cycles showed no noticeable difference as compared to an unabraded sample. When the number of abrasion cycles at the test maximum of 100 did not produce a noticeable difference, >100 is indicated. This table also shows the ImageXpert® gray value differences from unabraded black and white patches for the number of abrasion cycles that produced the JND from visual assessment. Positive numbers are an increase in gray value, negative numbers are a decrease in gray value.

No abrasion damage was seen with any of the abrader materials with the ¼-lb weight or with the polyester abrader using the 2-lb weight even with the maximum of 100 cycles used for the photographic materials. Glossmeter data from the black patches in photographs could not be used to correlate with visual observations because in most cases the visual observation was more obvious in the unprinted (white) areas of the samples that was not measured rather than in the black patches. It is clear from the data in Table 1 that visual assessment of JNDs for gloss change does not correlate with dark smear JND.

Table 1: Photograph printer/paper combinations and envelope paper abrasion conditions for dark smear and gloss JND.

Photographs

Abrader Weight: 2-lb - Abrader: Envelope Paper

Printer	Paper	Dark Smear JND Cycles	White Patch IX Change	Black Patch IX Change	White Area Gloss JND Cycles
Chromogenic	AgX	>100	0.1	0.1	25
D2T2	D2T2	>100	-3.0	0.0	50
IJ Pigment 1	Fine Art	5	5.1	0.0	>100
IJ Pigment 2	Photo 1 Matte	25	4.7	-0.6	>100
IJ Dye 1	Photo 1 Matte	>100	4.3	-0.9	>100
IJ Dye 1	Photo 1 Glossy	>100	-0.1	-0.1	100
IJ Dye 2	Photo 2 Glossy	>100	0.6	-1.0	>100

Table 2: Photograph printer/paper combinations and paper back abrasion conditions for dark smear and gloss JND.

Photographs

Abrader Weight: 2-lb - Abrader: Paper Back

Printer	Paper	Dark Smear JND Cycles	White Patch IX Change	Black Patch IX Change	White Area Gloss JND Cycles
Chromogenic	AgX	>100	-0.4	0.0	50
D2T2	D2T2	>100	-0.7	-0.1	50
IJ Pigment 1	Fine Art	5	5.4	-0.3	>100
IJ Pigment 2	Photo 1 Matte	10	3.3	-0.4	>100
IJ Dye 1	Photo 1 Matte	>100	3.5	-1.2	>100
IJ Dye 1	Photo 1 Glossy	>100	0.0	0.1	>100
IJ Dye 2	Photo 2 Glossy	>100	1.5	-0.3	>100

Figure 2 shows the relative sensitivity of photograph printer/paper combinations to abrasion. In this case, the white patch gray value change was produced with the paper back abrader under a 2-lb weight with 100 abrasion cycles.

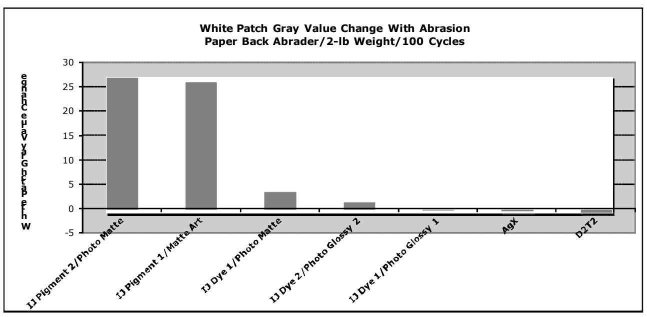

Figure 2: *Relative sensitivity of photographic printer/papers to abrasion.*

Results and Discussion - Documents

Tables 3 and 4 for dark smear with a 2-lb abrasion weight for both envelope paper and paper back abraders show the number of abrasion cycles that produced a JND for documents from visual observation. As was the case for photographs, fewer cycles showed no noticeable difference as compared to an unabraded sample. When the greatest number of abrasion cycles in the test (1000) did not produce a noticeable difference, >1000 is indicated. This table also shows the ImageXpert gray value differences from unabraded black and white patches for the number of abrasion cycles that produced the JND.

As was the case for photographs, no abrasion damage was seen with any of the abrader materials with the ¼-lb weight or with the polyester abrader using the 2-lb weight even with the maximum of 1000 cycles used for the document materials. Gloss was not measured for the document printer/paper combinations.

Table 3: Document printer/paper combinations and envelope paper abrasion conditions for dark smear JND.

Documents

Abrader Weight: 2-lb - Abrader: Envelope Paper

Printer	Paper	Dark Smear JND Cycles	White Patch IX Change	Black Patch IX Change
B&W EP	Plain1	5	5.5	3.5
B&W EP	Plain2	5	7.1	2.0
Color EP 1	Plain1	500	1.0	-2.0
Color EP 1	Plain2	100	6.9	0.1
Color EP 2	Plain1	>1000	-0.9	-0.5
Color EP 2	Plain2	500	2.0	-0.9
IJ Pigment 1	Plain 2	5	2.8	-0.1
IJ Pigment 2	Plain 1	25	5.8	1.0
IJ Hybrid 1	Plain 1	5	7.4	-1.5
IJ Hybrid 2	Plain 1	5	8.3	-1.7

Table 4*:* Document printer/paper combinations and paper back abrasion conditions for dark smear JND.

Documents

Abrader Weight: 2-lb - Abrader: Paper Back

Printer	Paper	Dark Smear JND Cycles	White Patch IX Change	Black Patch IX Change
B&W EP	Plain1	5	6.3	0.6
B&W EP	Plain2	5	8.1	3.4
Color EP 1	Plain1	500	9.9	0.4
Color EP 1	Plain2	500	9.2	-0.8
Color EP 2	Plain1	>1000	1.8	-0.2
Color EP 2	Plain2	500	0.4	-0.7
IJ Pigment 1	Plain 2	10	5.0	0.0
IJ Pigment 2	Plain 1	25	4.5	1.1
IJ Hybrid 1	Plain 1	5	3.4	-1.9
IJ Hybrid 2	Plain 1	5	8.8	-1.4

Figure 3 shows the relative sensitivity of document printer/paper combinations to abrasion. In this case, the white patch gray value change was produced with the paper back abrader under a 2-lb weight with 1000 abrasion cycles.

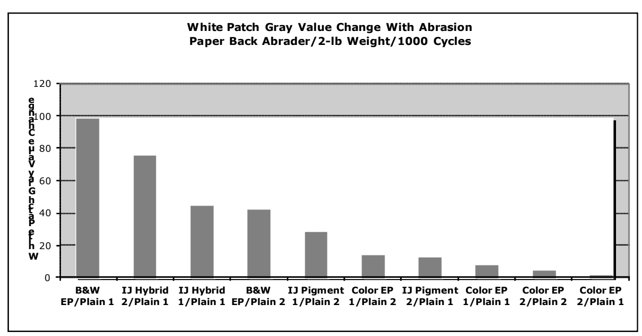

Figure 3: *Relative sensitivity of document printer/papers to abrasion.*

Conclusions and Recommendations

1. Results from the abrasion utilizing the ¼-lb weight indicated that sorting sheets in small stacks or sliding prints in and out of envelope paper enclosures 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. Because no noticeable damage was seen with the use of polyester sheets as the abrader even with the 2-lb weight it is clear that this material would be preferred over envelope paper to store digital prints.
3. With some digital printer/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.
4. Image analysis gray value differences do not correlate with visual assessment of JND, so this measurement cannot be used as a quantifiable threshold limit for this property.
5. Results from this investigation confirm earlier work that IJ pigment prints are more prone to abrasion damage than IJ dye prints and black and white EP prints are more prone to abrasion than color EP prints. Also, chromogenic and D2T2 prints are relatively insensitive to abrasion damage.

References

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The scope of this project did not include scuff and scratch sensitivity of digital prints so no results on these characteristics are provided in this paper.

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 nine papers on the permanence properties of digital prints since 2007.