Abrasion of Digital Reflection Prints

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Abstract

An increasing number of color prints are now obtained from digital information with the hard copy being produced by ink jet, thermal dye transfer, and electrophotographic technologies. The permanence of these materials is of paramount concern. While there has been considerable investigation on the image stability of these materials, as it is affected by heat, humidity, light, and pollutants, there has been relatively little on their physical integrity. A physical property of primary interest is abrasion resistance. Damage to prints can occur when they are pulled from a stack or when they are accidentally subjected to rubbing action by other materials such as storage enclosures. This study was primarily concerned with the suitability of standard test methods for these materials. Abrasion resistance was evaluated using two standard abrasion tests; the Ugra Rub Test and the Sutherland® Rub Test. Experiments were made on ink jet prints on both swellable and microporous paper as well as on electrophotographic prints. The back side of one sheet of paper was rubbed against the image side of another, simulating a real-life situation. Additional abrading surfaces were a standard envelope paper, a smooth polyester sheet, and a relatively smooth abrasive cloth. Abrasion damage was determined by density change, by gloss change of a 1.0 density patch, by average grey levels, by delta E, and by the degree of smudging of colorants onto an adjacent Dmin area. These quantitative tests were compared to visual ratings. Both the Ugra and Sutherland tests produced similar abrasion actions, although the latter was more severe.

Introduction

There has been extensive research on the permanence of digital images as affected by external factors, specifically, investigations focused on environmental factors such as the degradation of digital images due to the effects of ozone, humidity, heat, and light. However, there has been a paucity of information on the physical changes in digital images due to the application of physical forces such as flexing and rubbing with abrading materials. Undoubtedly the physical abuse of an image can be just as deleterious as a change in the color characteristics.

This paper deals with the abrasion resistance of reflection digital images. Studies on this property have been reported for photographic film [1,2] but only limited work has been published for photographic reflection images [3, 4, 5] .

This is a preliminary study to investigate the suitability of various testing procedures and methods to quantify the abrasive damage. It does not provide an evaluation of the relative abrasion susceptibility of the different types of reflection print materials. Once a testing procedure has been found that is reproducible and that simulates practical experience, the relative behavior of different digital processes will be determined. An additional purpose of this study is to provide input to the appropriate committee in the International Standards Organization so that a standardized procedure can be published.

Test Methods

Many different means of abrading imaging materials have been devised to simulate real-life conditions. Scratch testing has consisted of determining the load on a sapphire stylus that first produces a scratch, or of measuring the haze produced by a series of scratch lines. A carborundum test involves dropping a standardized weight of silicon carbide on a rotating specimen and measuring the resultant haze. A wheel brush test has been developed that consists of a mounting a rotating horse hair brush against a specimen and measuring the resulting damage. A commercial test instrument is the Taber® Abraser. It produces damage by means of a rotating pair of abrasive wheels. These tests have been applied to photographic film [2] but never to reflection prints. They do not duplicate the type of action that typically causes abrasive damage to prints.

The Sutherland® Rub Test (available from the Danilee Co., 27223 Starry Mountain, San Antonio, Texas 78260) is another commercial rub test that has been standardized in a number of American Society for Testing and Materials (ASTM) documents. It consists of placing the material to be tested on a rubber pad fastened to a 2 5/8" x 6" block attached to the base of the instrument. Abrasion is accomplished by securing the abrading material to a rubber pad that is fastened to a 2" x 4" receptor block surface. The latter is in contact with the test material. The weight of the receptor block has been standardized by the manufacturer at either two or four pounds, but other weights are available. The receptor block is rubbed against the material for a set number of cycles. This test is intended to simulate the abrasion that occurs by the sliding of a print over a contacting surface. This can result when prints are removed from a stack of similar prints or an envelope, when they are slid over another surface, or during transport of a stack of prints. This is one of the procedures used in this study. Specimens were abraded after both ten and 50 cycles with the two-pound weight at 21°C, 50% RH.

A second rub test was also evaluated. The Ugra Rub Tester was developed by the Swiss Centre of Competence for Media and Printing Technology. It has a similar action to the Sutherland Rub Test but is hand-operated. It consists of a frame with a counter that holds the material in place and a 500-gram metallic block to which the abrading material is attached. Materials were tested after both ten and 50 cycles at 21°C, 50% RH.

There are two additional rub tests. The Gavarti Comprehensive Abrasion Tester (or GA-CAT) is a commercial instrument developed by Gavarti Associates in Milwaukee, WI.

It simulates the abrasion caused when printed materials are rubbed between abrasive surfaces. The crockmeter is another test method. Both of these tests have an abrasive action similar to that of the Sutherland Rub Tester and Ugra Rub Tester. However, the equipment for both is more complex and less flexible. They do not offer any apparent advantages over the other testers.

Evaluation

The samples abraded had both a uniform black density of 1.0 and an adjacent Dmin patch. The high-density black patch was obtained by printing with all colorants dictated by the printer driver to achieve this density. The Dmin patch was important to determine whether there was any image transfer (or smudge) from the abraded high-density area. Evaluation was determined by the following procedures:

1. Gloss measurements were used to determine the extent of damage in the 1.0 density patches. It 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 specimen.
2. Visual density measurements were determined before and after abrasion of the 1.0 density and Dmin patches.
3. In addition to densitometry, CIE colorimetric L*, a*, b* and delta E (CIE) measurements were made.
4. Image analysis utilized the software and hardware designed by ImageXpert, Inc. of Nashua, NH. Initial results provided analysis based on average gray-scale values. A relationship exists between this value and density. The gray scale values are from 0 to 255, where 0 is dark and 255 is light.
5. A visual assessment by a team of eight observers gave a subjective rating of abrasion damage using a scale of 1 to 10 (with 10 representing greatest severity).

Materials

A wide variety of materials are used for digital prints. In this preliminary study, tests were completed on four digital prints: ink jet images on microporous and swellable paper and both black-and-white and color electrophotographic prints. The abrading materials were the back side of the image paper, a standard envelope paper, a smooth polyester sheet, and a relatively smooth Micro-Mesh® (micro-abrasive cloth available from Micro-Surface Finishing Products, Inc., 1217 West 3rd St., P.O. Box 70, Wilton, Iowa, 52778). The last was chosen because of its uniformity and the expectation that it would cause measurable abrasive damage.

Experimental Results

All printed samples were first aged for a minimum of seven days at 21° +/- 2°C, 50% +/- 5% RH to allow both adequate dry-down time and moisture conditioning. All testing was done at this condition. In this preliminary work, three replicates were abraded and the averages reported.

Table 1 shows the change in either the 60° or 85° gloss values for the four digital prints. Positive values indicate a gloss increase, and negative values indicate a gloss decrease. It is interesting that three of the specimens showed a gloss increase as a result of abrasion. This is the equivalent of a polishing action. However, the ink jet specimen on swellable paper exhibited a gloss decrease, which is characteristic of a scuffing action. Consequently, it is the magnitude of gloss change that quantifies abrasive damage and not direction of change. These data also illustrate that the gloss change was consistently greater for the Micro-Mesh than for the back of the print, the polyester sheeting, and the envelope paper. With some combinations, abrasion caused streaking that was not uniform. While gloss measurements give a quantitative number, what is critical is whether this corresponds to a visual assessment of abrasive damage.

Table 1: Change in Gloss Measurements Using Sutherland Rub Test (2-lb. weight, 50 cycles)

Abrading Material	IJ Microporous	IJ Swellable	B&W EP	Color EP
Gloss Angle	60	60	85	85
Back of Print	2.2	2.3	0.7	3.4
Polyester	-3.0	2.7	-1.2	3.8
Envelope	17.3	1.0	-0.4	4.6
Micro-Mesh	39.5	-16.8	13.9	13.1

Visual density and delta E measurements did not show the magnitude of change given by the gloss values. With some materials, a slight increase in density was noted after abrasion. This can be explained by high-density dots being smudged into adjacent low-density areas between the dots, creating a slight overall density increase. However, the changes found were small. Smudging or smearing was best determined by the change in the low-density patch adjacent to the 1.0 density patch that was abraded. For example, the visual density measurements showed a measurable density increase of 0.13 in the Dmin area for the black-and-white electrophotographic image after 50 cycles with the Sutherland method.

The changes after abrasion by the Sutherland test were clearly greater than with the Ugra test. This is to be expected because the Sutherland test employs approximately twice the weight on the abrading material. The Sutherland test, being automatic, proved to be easier to use with less chance of operator error, and it gave the same rankings as the Ugra. Consequently, the Sutherland apparatus was preferred.

In Table 2 the various quantitative evaluation methods are compared to the visual ranking by eight observers for three digital prints after abrasion by both the Ugra and Sutherland rub tests after ten and 50 cycles. Rank order for the average of the observers was compared to the objective measurements to determine how well the latter correlated with the visual rankings. Analysis was performed using Spearman's Rank correlation coefficient. An r_s value close to 1 indicated a high correlation. This table showed the highest correlation when determinations were made on smudging of the Dmin patch by either density change, delta E change, or change in average grey level.

Table 2: Spearman's Rank Correlation Test of Visual Ranking Versus Other Evaluation Methods

Evaluation Method	r_s	95% confidence	99% confidence
% gloss change	0.27	no correlation	no correlation
% density change in 1.0 density patch	0.62	positive correlation	no correlation
% density change in Dmin patch	0.90	positive correlation	positive correlation
Delta E in 1.0 density patch+	0.57	positive correlation	no correlation
Delta E in Dmin patch	0.84	positive correlation	positive correlation
ImageXpert change in 1.0 density patch	0.77	positive correlation	positive correlation
ImageXpert change in Dmin patch	0.89	positive correlation	positive correlation

Discussion

It must be emphasized that this is a preliminary study. Only four materials were evaluated, and testing is needed on additional ink jet prints with pigment images and dye diffusion thermal transfer prints. In addition, studies are required with various paper finishes such as glossy, matte, plain, coated, and uncoated.

This study indicated that the Sutherland Rub Test appeared to be the best apparatus for determining the abrasion characteristics of digital prints. However, the optimum means of evaluating change requires greater study, since not all of the quantitative measurements agreed with the visual assessment. Studies to date suggest that measurement of smudging were the most sensitive both visually and quantitatively.

References

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Author Biography

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