Brittleness of Digital Reflection Prints

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Abstract

Although cracking of image layers and/or buckling of papers is a potential problem for some digital prints under adverse handling conditions, there has been little investigation of this behavior. This study reports the results of using the ISO standard Wedge Brittleness Test, originally developed for traditional photographic films and papers, to explore the relative sensitivities of a variety of digital print types at 23°C/15% RH and 50% RH. The quantitative measurement in this test is the largest diameter in a wedge at which cracking or buckling first occurs. This method proved to be suitable for digital prints and allowed the examination of specimens for cracks and buckling. Some prints required very close examination after being subjected to the applied stress because many of the resulting defects were microscopic. The relative severity of the resulting damage is also discussed. Results are reported for over two dozen unprinted papers as well as mid-density prints produced by ink jet, dye diffusion thermal transfer, offset lithography and electrophotographic printing methods as well as by the traditional wet chemical process. There were wide differences in behavior between materials. In general, as might be expected, damage was more severe with some papers at the lower humidity condition.

Introduction

There has been considerable research on the effects of environmental factors such as ozone, humidity, heat, and light on the degradation of digital prints, but there has been little investigation and no published research on the effects of cracking and/or buckling of these materials under adverse handling conditions.

An ISO standard Wedge Brittleness Test (ISO 18907:2000E) exists for film and paper, and studies of cracking and/or buckling characteristics have been reported for photographic film and paper [1, 2], but this is the first published research for this property of digital reflection paper prints. A wide variety of digital print materials exist utilizing various technologies to enhance image quality, ease of handling, and image permanence. All of these materials must have sufficient flexibility to withstand the stresses imposed during use.

Different types of print materials can behave differently when subjected to flexing stresses. In some papers that utilize coated layers to accept dyes or pigments, fine cracks (defined here as "micro brittleness") can occur in these layers. In other papers, buckling (defined here as "macro brittleness") or complete tearing of the paper can occur when it is subjected to severe bending stress. Figure 1 is a photomicrograph of a cross-section of an inkjet paper showing cracks in the image-receiving layer, indicated by the arrows. Figure 2 is a photomicrograph of a cross-section of a fine art inkjet paper illustrating buckling in the paper support and a void in the image-receiving layer.

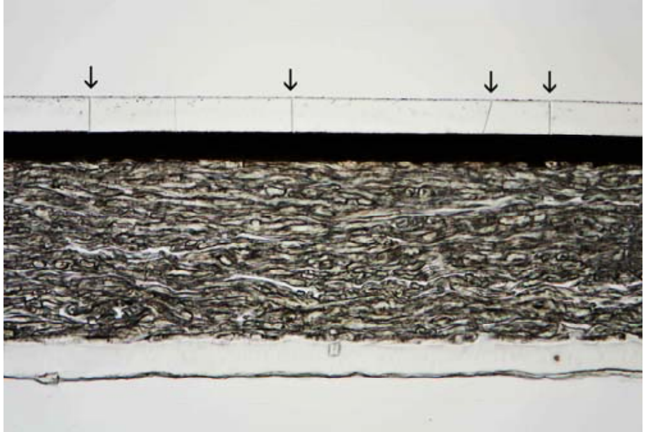

Figure 1: *Cross-section photomicrograph of an inkjet paper showing cracks.*

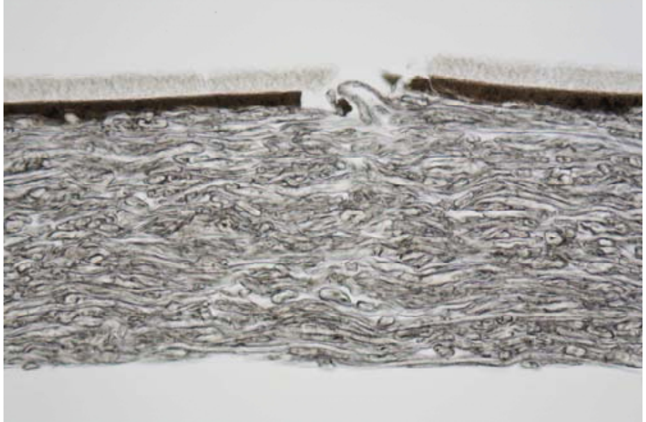

Figure 2: *Cross-section photomicrograph of an inkjet paper showing buckling.*

It is known that brittleness of gelatin photos can be adversely affected by low relative humidity. Consequently, the brittleness tests in this investigation were carried out in a carefully controlled temperature and relative humidity environment. Because brittleness can vary with the orientation of the paper, tests were performed in both the length and width directions of samples.

The wedge test for brittleness described in ISO 18907 subjects the material to various degrees of strain in a simple bending action. It has been an accepted brittleness test method for many years and has correlated with behavior under practical applications. Another method described in ISO 5626 consists of a flex test in which the specimen is subjected to a repeated folding action until it breaks [3]. This type of test does not represent the type of handling that digital reflection prints are likely to encounter in collections.

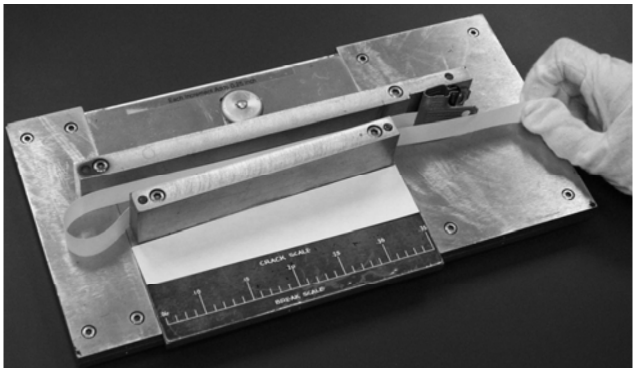

Figure 3: Wedge brittleness apparatus with a clamped sample and leader.

Test Method and Evaluation

Raw (unprinted) specimens, others printed to an approximate sRGB of 128, 128, 128, and some processed with no printing were conditioned for at least three days in the test environment prior to testing. Two test environments were studied: 23°C ± 1°C at 15% RH and 23°C ± 1°C at 50% RH ± 3% RH. Three replicate tests at each condition were performed in a large test chamber. The wedge brittleness test method described in ISO 18907 was used. The apparatus (Figure 3) consists of two non-parallel plates or jaws that form a wedge, and it has a clamp at the narrow opening of the wedge that holds the sample.

A paper leader was attached to each of the samples because of their limited length.

The test procedure for micro brittleness (cracking) and macro brittleness (buckling) is provided in detail below.

1. One end of an 11-inch by 5/8-inch specimen is fastened in the clamp with a leader attached to the other end.
2. The specimen is looped; the side intended for printing is positioned on the outside (as described in the ISO standard) through the wedge with the unclamped end protruding through the narrow opening.
3. The specimen end is rapidly pulled through the narrow wedge opening by hand.
4. The largest wedge separation (i.e., diameter) at which the paper shows buckling is the measure of brittleness.

It was necessary to examine the samples very carefully under magnification and/or raking lighting conditions to determine the largest wedge separation at which the samples showed the first indication of cracking or buckling. There is some subjectivity in the analysis because observer judgment is required to determine where in the sample this occurs. In order to eliminate operator-to-operator variability, a single observer judged all the samples.

Materials

A wide variety of digital print papers were used in this study. These included the following:

- Digital press papers (DP), both coated glossy and matte types as well as uncoated paper
- Coated photo papers for both inkjet (IJ) dye and pigment printers
- Fine art papers for dye and pigment printers
- Uncoated papers for black-and-white and color electrophotographic (EP) printers
- A dye sublimation (D2T2) paper for the corresponding dye sublimation printer

Chromogenic (AgX) papers and offset litho papers (OL) also were tested for comparison with the digital print papers.

Table 1: Results for printed paper and printer types, showing the largest average wedge separation (inches) of three samples, where the first indication of cracking or buckling occurred, tested in the length direction, and the standard deviation.

Printed (P) Sample ID	Paper Type	Printer Type	Length Brittleness at 23°C/15%RH		Deformation Type
			Average	Standard Deviation	
1P	IJ Plain Uncoated	IJ Dye	0.30	0.03	Buckle
2P	IJ Plain Coated	IJ Dye	0.35	0.02	Buckle
3P	Plain Uncoated	IJ Solid	0.38	0.03	Buckle
4P	IJ Dye Porous	IJ Dye	0.30	0.02	Crack
5P	IJ Dye Swellable	IJ Dye	0.44	0.02	Crack
6P	Plain Uncoated	IJ Pigment	0.48	0.03	Buckle
15P	D2T2	D2T2	0.23	0.01	Buckle

Table 2: Results for unprinted papers types, showing the largest average wedge separation (inches) of three samples, where the first indication of cracking or buckling occurred, tested in the length direction, and the standard deviation.

Unprinted (U) Sample ID	Paper Type	Length Brittleness at 23°C/15%RH		Deformation Type
		Average	Standard Deviation	
1U	IJ Plain Uncoated	0.42	0.03	Buckle
2U	IJ Plain Coated	0.33	0.03	Buckle
3U	IJ Porous	1.60	0.01	Crack
4U	IJ Porous	0.71	0.04	Crack
5U	IJ Swellable	1.39	0.11	Crack
6U	IJ Swellable	0.55	0.04	Buckle
7U	IJ Porous	0.23	0.01	Crack
8U	IJ Plain Coated	0.28	0.01	Buckle

9U	IJ Porous	0.29	0.02	Buckle
10U	IJ Fine Art	0.38	0.03	Buckle
11U	IJ Fine Art	0.55	0.04	Buckle
12U	IJ Fine Art	0.35	0.02	Buckle
13U	B&W EP	0.35	0.03	Buckle
14U	Color EP	0.29	0.03	Buckle
15U	Plain Uncoated	0.38	0.03	Buckle
17U	D2T2	0.26	0.02	Buckle
18U	AgX	0.30	0.02	Buckle
20U	DP Uncoated	0.12	0.01	Buckle
21U	DP Coated Glossy	0.14	0.02	Buckle
22U	DP Coated Matte	0.29	0.08	Buckle
23U	OL Uncoated	0.35	0.04	Buckle
24U	OL Coated Glossy	0.13	0.01	Buckle
25U	OL Coated Matte	0.15	0.03	Buckle

Experimental Results and Discussion

A large amount of data was collected in this investigation; due to limited space, only some has been included. All results are provided as the deformation type (cracking or buckling) and the largest diameter to initial deformation, in inches.
(See Tables 1 and 2.)

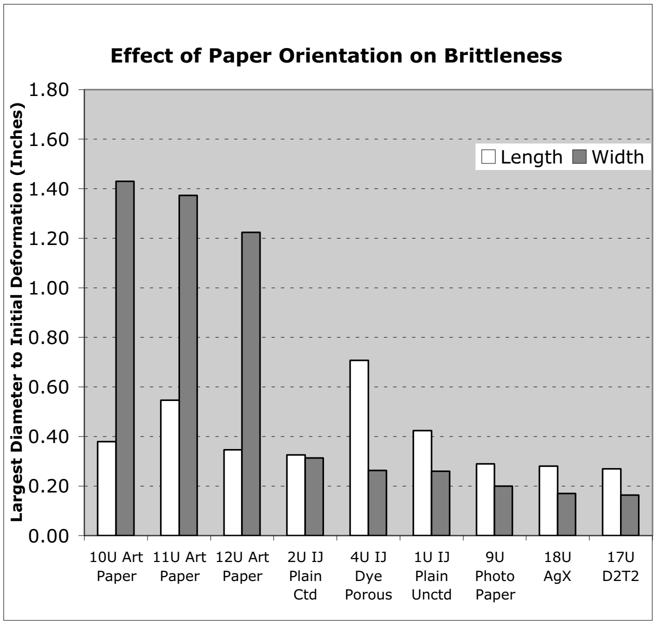

***Figure 4**: Largest Diameter to Initial Deformation (Inches) for Fine Art Inkjet and Some Other Photo Papers, Unprinted, Length vs. Width at 23°C/15% RH*

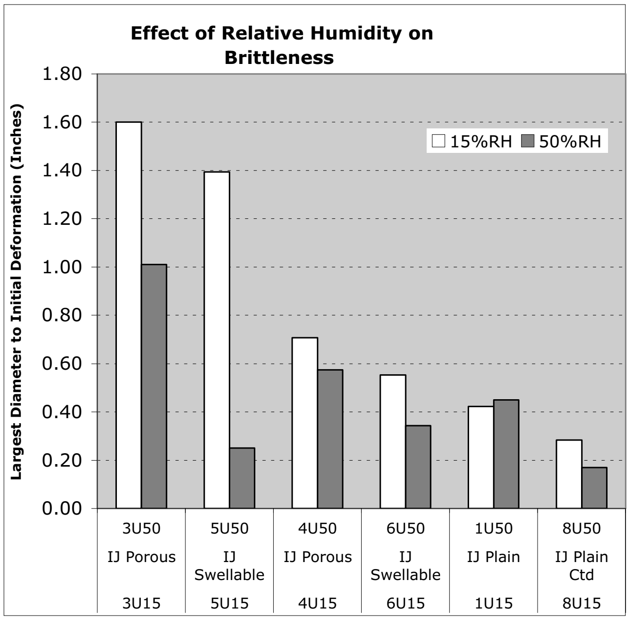

***Figure 5:** Largest Diameter to Initial Deformation (Inches) for Various Inkjet Papers 15% RH vs. 50% RH, Length Unprinted at 23°C*

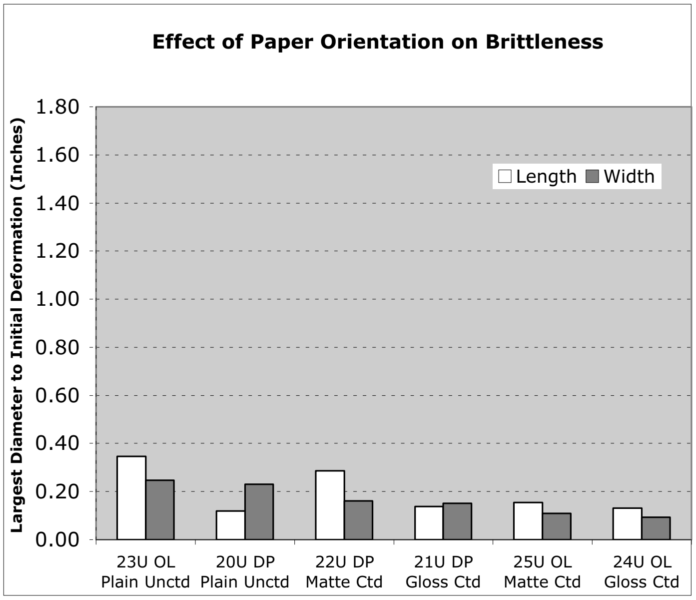

Figure 6: Largest Diameter to Initial Deformation (Inches) for Digital Press and Offset Litho Papers, Unprinted Length vs. Width at 23°C/15% RH

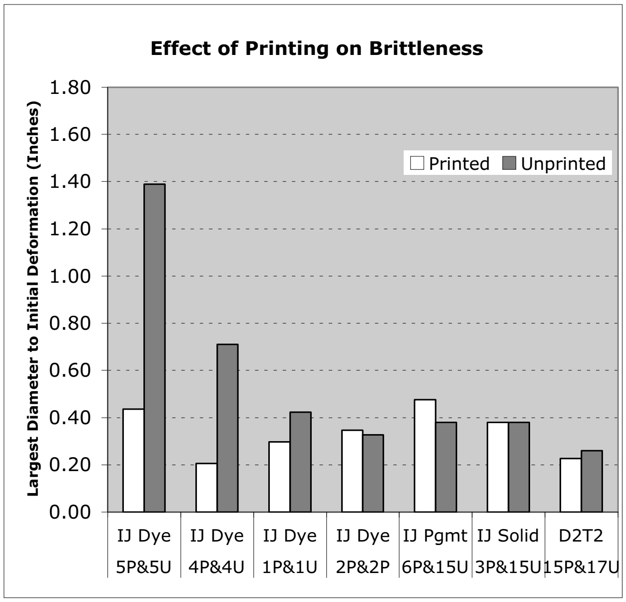

Figure 7: Largest Diameter to Initial Deformation (Inches) for Various Inkjet Papers Printed vs. Unprinted Length at 23°C/15% RH

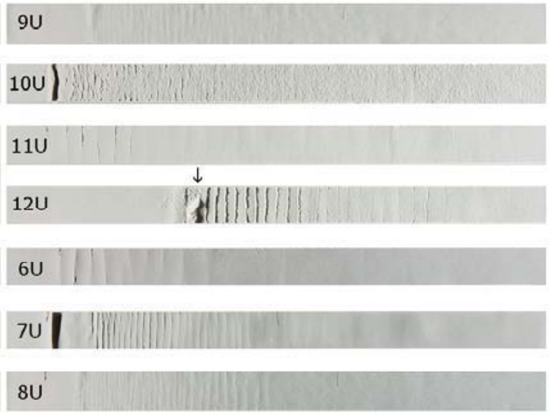

Figure 8: Severity of buckling caused by the test procedure.

Figure 8 shows a series of samples illuminated with raking light to best illustrate the severity of buckling caused by the test procedure. This buckling was most severe with the fine art papers and some of the glossy inkjet papers. Some samples were physically torn during testing; an example (Sample 12U) is seen under the arrow.

Conclusions

In general, the following conclusions can be reached:

1. Large differences in behavior were seen between papers. Some papers showed cracks in the image-accepting layers before buckling occurred; others only had buckling in the paper support and/or actually tore during the testing. The severity of damage varied considerably among samples and is probably more important than the wedge diameter at which a given sample first exhibited cracking or buckling (Figure 8).
2. In some cases, large differences in brittleness occurred between the length and width paper orientation. The fine art papers showed the greatest differences (Figures 4 and 6).
3. The most severe brittleness behavior was found in the inkjet fine art papers and some glossy inkjet papers intended for photo printing (Figures 4, 5, and 7).
4. The chromogenic (AgX), dye sublimation (D2T2), offset, digital press papers and plain uncoated papers had the least severe brittleness behavior (Figures 4 and 6).
5. When printed, some of the inkjet papers showed a reduced brittleness tendency; others showed almost no difference between printed and unprinted samples (Figure 7).
6. More severe brittleness behavior was observed at 15% RH than at 50% RH (Figure 5).
7. Some digital prints can be significantly more sensitive to cracking than traditional chromogenic prints.

References

[1] ISO 18907:2000(E) Imaging Materials—Photographic Films and Papers—Wedge Test for Brittleness (International Organization for Standardization, Geneva, Switzerland, 2000).

[2] P. Z. Adelstein, "Wedge Brittleness Test for Photographic Film," Photo. Sci. and Engin., 1, 63 (1957).

[3] ISO 5626:1993(E) Paper—Determination of Folding Endurance, (International Organization for Standardization, Geneva, Switzerland, 1993).

Author Biography

Dr. Salesin received his B.S. in chemical engineering from the University of Michigan and both his M.S. and PhD in chemistry from Case Western Reserve University. He retired from the Eastman Kodak Company in 1997 after 36 years of employment in their research laboratories and several manufacturing divisions. He joined the Image Permanence Institute in 2004 where he has been involved in evaluating the permanence properties of magnetic tape and digital prints.