Accelerated light aging of digital prints

Ákos Borbély, Csaba Horváth, Rozália Szentgyörgyvölgyi

Óbuda University
Doberdó út. 6, H-1034 Budapest, Hungary
E-mail: akos.borbely@rkk.uni-obuda.hu

Abstract

Products exposed to sunlight will fade, and loose color contrast apparently. Resistance to fading is a crucial problem especially in the case of high quality products. A close match is desired between the optimum and the target lifetime of printed products placed outdoors or in a store window. Most if not all the components of the printing ink (e.g. pigments, solvent) are responsible for the resistance against irradiation, temperature and other weathering conditions.

Accelerated aging devices simulate environmental parameters reliably, they provide stable irradiation, temperature and measurement conditions. While weathering instruments are popular laboratory devices, the effects of aging on the color quality of prints are less studied.

Our research work was aimed at the investigation and understanding of the parameters and processes of aging in case of prints produced by digital printing technologies. The study focused on the changes in visual quality of test prints on different substrates. We used Atlas Suntest XLS+ weathering instrument to investigate the resistance of digital prints against filtered sunlight. The analysis of the results revealed how the parameters of print optical quality gradually deviated from the original values.

Keywords: accelerated aging, artificial weathering, digital printing, color quality

1. Introduction

Weathering is the adverse response of material or products to climate, often causing unwanted and premature product failures. Costumers spend billions of Dollars or Euros every year to maintain products that inevitably degrade and to replace products that fail as a result of exposure to outdoor environment account for a significant portion of the total cost. There is opportunity to prevent deterioration and premature product failure through chemical and mechanical stabilization and through weathering tests (static weathering, laboratory accelerated weathering, natural accelerated weathering) to assess a material's durability. Many different testing options are available. The best option depends on the applications and objectives. For product development, it is vital to understand how to properly design and conduct these tests. The three factors that cause degradation are solar radiation (light energy), temperature, and water (moisture). But not just "how much" of each of these factors ultimately causes degradation to materials, because different types of solar radiation, different phases of moisture, and temperature cycling have a significant effect on materials on exposure. These factors, in conjunction with secondary effects such as airborne pollutants, biological phenomena, and acid rain act together to cause "weathering" (Atlas Weathering Testing Guidebook, 2004; Rahauser, Schönlein, 2011).

The solar radiation that reaches the earth's surface consists of wavelengths between 295 and 3000 nanometer. This terrestrial sunlight is commonly separated into three main wavelength ranges: ultraviolet (UV), visible (VIS) and infrared (IR). Wavelengths between 295 and 400 nm are considered the ultraviolet (UV) portion of the solar spectrum, making up between 4-7% of the total radiation. Ozone in the stratosphere absorbs and essentially eliminates all radiant energy below 295 nm. Extremely sensitive instruments may detect radiation below 295 nm, but this amount is considered negligible by most experts. The discussion of direct and diffuse radiation is important when considering radiant energy received at different orientations to the sun.

The result of the degradation characteristics of a material as a result of radiation depends on:

- the quality and quantity of radiant energy the material is exposed to,
- the wavelengths of radiation absorbed by the material,
- whether or not the absorbed radiation has enough energy to cause a chemical change, which could lead to material degradation.

The *temperature* of materials exposed to solar radiation has an influence on the effect of the radiation. Also, the temperature of material exposed to natural sunlight is determined by number of factors. Specimen surface temperature is a function of ambient temperature, specimen solar absorptivity, solar irradiance, and surface conductance.

Water is one of the substrates in our environment that is everywhere, whether in the form of humidity, rain, dew, snow, or hail. All materials used outdoors are exposed to these influences. Water also can be directly involved in the degradation reaction in a chemical sense (Zielnik, 2004; Bond, 2011).

The apparent sign of degradation in case of products exposed to sunlight is fading, loss of color contrast. Resistance to fading is a crucial problem especially in the case of high quality printed products, fading should be minimal during the target lifetime of products placed outdoors or in a store window. Most if not all the components of the printing ink (e.g. pigments, solvent) are responsible for the resistance against irradiation, temperature and other weathering conditions (Goudie, Viles, 2008). Therefore it is important to collect correct information on the weather resistance and aging properties of a certain product. There are numerous reliable methods regarding artificial aging and weathering of different products. Controlled outdoor testing is the most common, during which the simultaneous effect of the environment, weather and exposure to sunlight is investigated. The disadvantage of this method is the dependence on local climate and changing measurement conditions. Accelerated aging devices simulate environmental parameters more reliable, they provide stable irradiation, temperature and measurement conditions. While weathering instruments are popular laboratory devices, the effects of aging on the color quality of prints is less studied.

Our research work was aimed at the investigation of the changes of parameters that describe visual quality during aging in case of prints produced by digital printing technologies.

2. Experimental

We used an Atlas Suntest XLS+ weathering testing instrument for the aging of the specimen, the device monitored irradiance, temperature and relative humidity of the test chamber. A window glass filter was applied to simulate terrestrial sunlight entering through the glass window of a display compartment. Average irradiance on the sample plane was 50 W/m^2 in the 300 nm - 400 nm range, and 765 W/m^2 in the 400 nm - 800 nm range.

In order to investigate colour changes, we designed the test chart (figure 2). We included in the test image color control patches of primary and secondary colors, tonal scales and 400 patch test chart for profiling and calculations of the reproducible gamut.

Two test prints made with different digital printing techniques, they were subjected to measurement in view of the changes occurring due to radiant exposure. A Canon Pixma MP650 inkjet and a Canon Imagepress C1 electrophotographic press was used to print test samples. Two types of self-adhesive substrates were used: matte (Ritrama 70 g/m^2 face, 110 g/m^2 backing) and semi-gloss (JAC Duro 2000 70 g/m^2 face, 110 g/m^2 backing). Samples were printed under normal everyday conditions at room temperature.

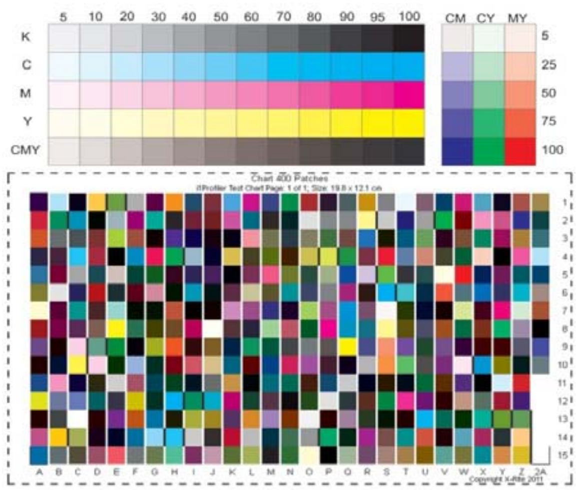

Figure 1:
Test chart printed by inkjet and electrophotographic technologies on two types of substrates. Optical properties were measured at stages of the aging process

We studied the test prints in the weathering equipment under the conditions of the ISO 4892-2 method B6 standard to investigate the resistance of digital prints against filtered sunlight, in this case without wetting. Initially the temperature of the test chamber was 24 °C, and then during the test, the thermometer inside the test chamber measured a temperature increase up to 65 °C. After completed stages of the accelerated aging process we measured parameters of the optical quality of the prints. Specimen were aged in steps of 48 hours, inkjet prints were aged for 144 hours, electrophotographic prints were aged for 192 hours altogether. After the 48 hour aging optical density, tone value increase and color differences and color gamut of the specimen were measured. For the evaluation of optical density and tone value increase (TVI, %) a Gretagmacbeth D19C reflection densitometer, for color measurement a Gretagmacbeth X-Rite Spectroeye spectrophotometer and Eye-One IO automated scanning table were used. Intensive irradiation alters color quality and the quantities of the corresponding properties. Before placed into the instrument, both samples were subjected to the measurement of the density of the primary colors and the tone value increases of all the tone scales. The L*a*b* color coordinates of the primary and secondary colors properties as well as color gamut were determined again after every 48 hours of exposure.

3. Results and discussion

As a natural consequence of the irradiation we expected the samples to fade. However, fading was not visually observable at a first glance after the first 48 hour aging period. Optical density values were de-creasing (figure 2) with radiant exposure, mostly affected were the magenta and yellow inkjet process colors. In order to obtain information on the magnitude of the changes on a visual scale, we measured the CIELAB values of the full tone process and secondary colors and calculated color differences between the original and the aged specimen in CIE 1976 ΔE^*_{ab} units. The results are shown in figure 3 for the process colors of the inkjet and electrophotographic press on the two substrates. The highest color difference values were found with the yellow and magenta inks in every case. We also investigated the secondary colors (R, G, B) together with chromatic black (CMY).

Figure 4 shows that the magnitudes of color differences are in the same ranges for every substrate-technology combinations. The largest color shifts occurred in case of the red, caused by the high level deviations of magenta and yellow. Color shifts were above threshold level already after the first 48 hours of exposure in all cases.

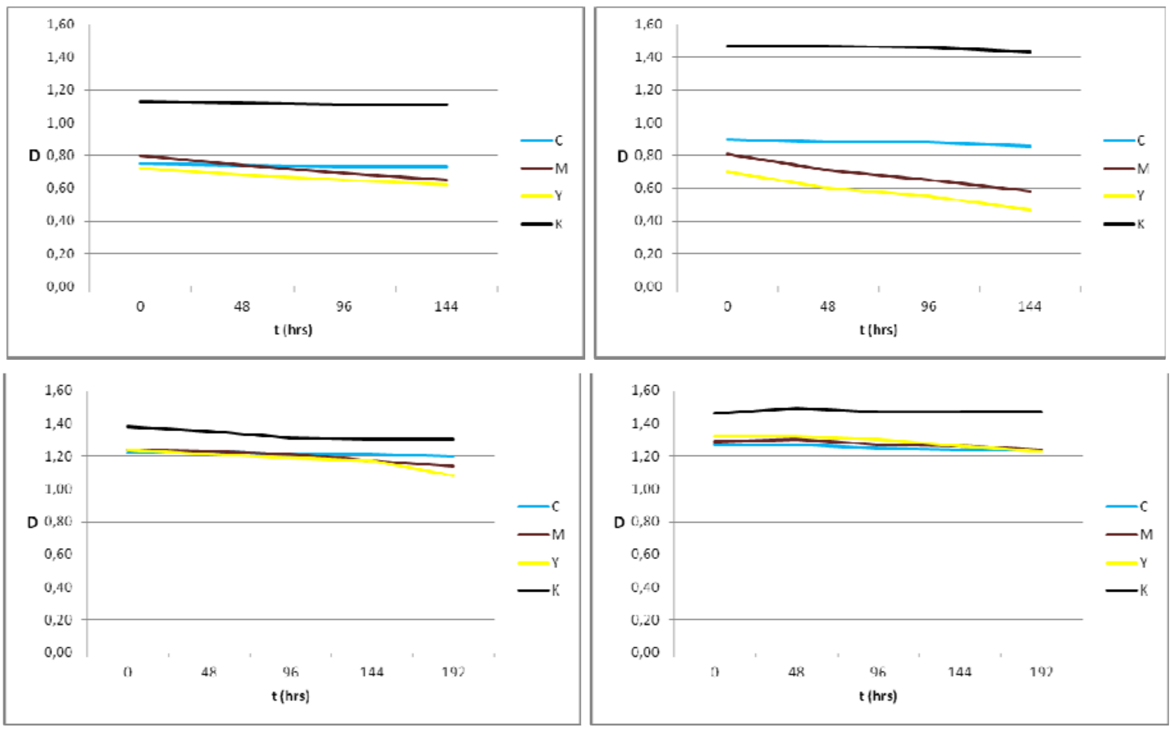

Figure 2: Optical density values of full tones of process colors (C, M, Y, K) during the 144 and 192 hours aging process. The diagrams show test prints on substrate 1 (left) and substrate 2 (right) printed using inkjet (upper row) and electrophotographic technology (lower row)

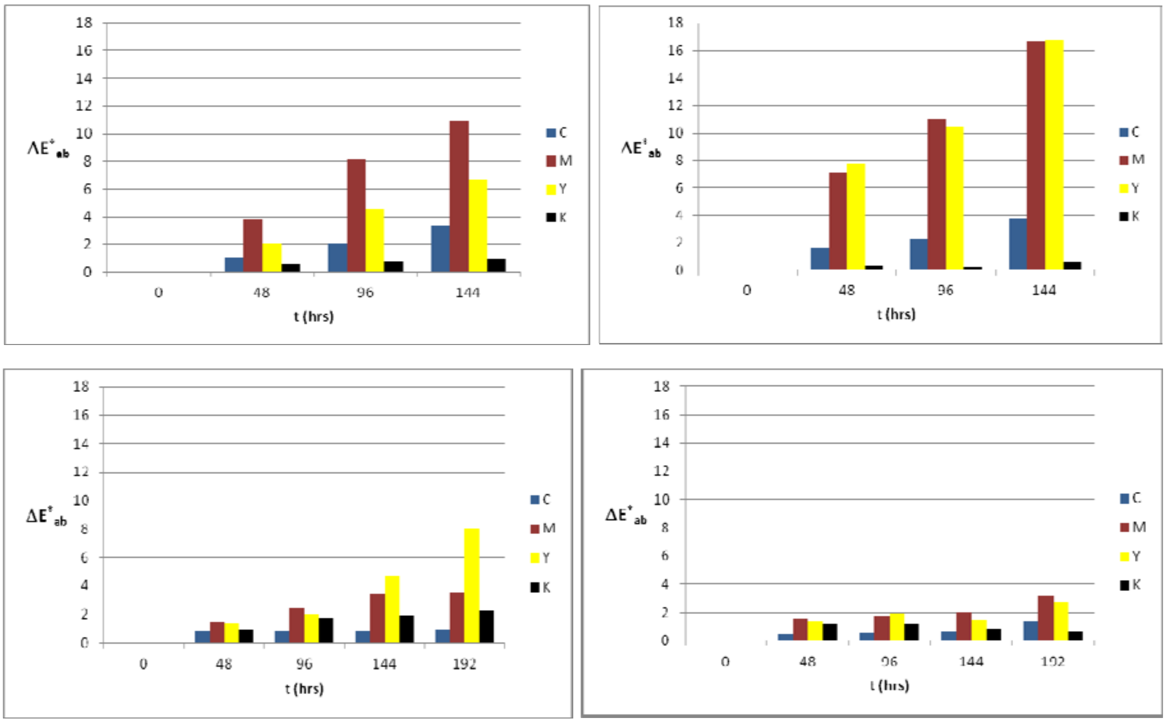

Figure 3: Color differences of solid patches of process colors (C, M, Y, K) at 48 hour steps of aging. The diagrams show test prints on substrate 1 (left) and substrate 2 (right) printed using inkjet (upper row) and electrophotographic technology (lower row)

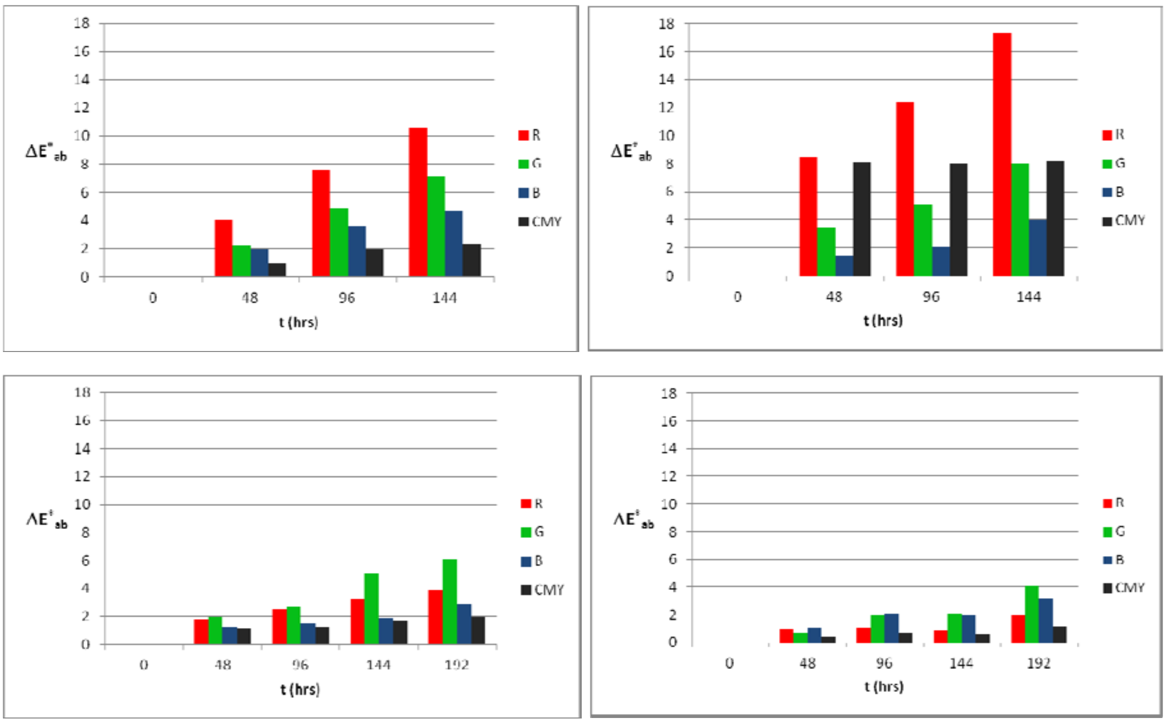

Figure 4: Color differences of solid patches of secondary colors (R, G, B) and chromatic black (CMY) at 48 hour steps of aging. The diagrams show test prints on substrate 1 (left) and substrate 2 (right) printed using inkjet (upper row) and electrophotographic technology (lower row)

We computed the range of reproducible colors (gamut) using a software tool commonly applied in proofing color workflows to visualize and compare color gamut volumes. Standard ICC printer profiles were gene-rated based on measurements of a CMYK chart with 400 patches, which was part of our test chart. We used an X-Rite EyeOne Pro measurement device and profiling software together with an i1 iO scanning table. The obtained profiles were loaded to a gamut visualization software, to calculate printable gamut in CIELAB color space volume units. The gamut sizes are shown in table 1, as relative values, the initial value before the aging process is taken as reference. The reproducible color gamut decreased by more than 40% in case of inkjet prints, while with electrophotographic technology gamut volume shrinking remained within 10%.

Table 1: Relative values of computed printable gamut volumes on self-adhesive substrates (s1 and s2) printed using inkjet and electrophotographic technologies

	Inkjet		Electrophotographic	
exposure time	s1	s2	s1	s2
0 h	1,00	1,00	1,00	1,00
48 h	0,90	0,79	0,96	0,98
92 h	0,78	0,71	0,95	0,98
144 h	0,70	0,59	0,94	0,98
192 h			0,93	0,98

4. Conclusions

In our discontinuous light aging experiment we tested prints produced using inkjet and electrophotographic technologies on two types of self adhesive substrates. Our samples were irradiated by window filtered sunlight in a weathering testing instrument for 48 hour terms, after each such term optical properties were measured. We experienced, that 48 hours of standard window filtered solar irradiation was enough to change optical characteristics significantly. The largest color deviations were found in case of the magenta and yellow process colors. We experienced 2% - 7% decrease of the reproducible color gamut in case of electrophotographic prints, while inkjet gamut shrinking was 30% - 40%.

References

Atlas Weathering Testing Guidebook. Atlas Electric Devices Company, 2001.

Bond, L. F., (2011): *Natural Outdoor Weathering*, "Időjárásállóság vizsgálat" (Investigation of weather resistance) conference. 2011.10.18. Budapest

Goudie, A. S., Viles, H. (2008)."*5: Weathering Processses and Forms*". In Burt T.P., Chorley R.J., Brunsden D., Cox N.J. & Goudie A. S., *Quaternary and Recent Processes and Forms*. Landforms or the Development of Gemorphology.4. Geological Society. pp. 129-164. ISBN 1-86239-249-8

Rahauser, O., Schönlein, A., (2011): A *look at Accelerated Photostability Testing for Packaging Food and Drink*. SunSpots, ATLAS Material Testing Solutions. Material Testing Products and News. Vol 41. Issue 89. pp. 1-4.

Zielnik, A. F.,: Weather Testing (2004): Why You Need It More Than Ever. Plastic Technology, March 2004 http://www.ptonline.com/articles/weather-testing-why-you-need-it-more-than-ever (accessed: Jan 10. 2012.)