The durability of UV ink-jet prints on special papers upon accelerated ageing

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Abstract

The aim of research work was to investigate the influence of accelerated ageing on unprinted and UV ink-jet printed special papers. Prints with CMYK color fields were made by UV ink-jet printer Océ Arizona 250 GT on three types of special papers; a fiber synthetic paper, a woodfree paper with included invisible security fibers and multitonal watermarks and another woodfree paper with security elements. On unprinted and CMYK printed special papers the moist heat treatment at 80°C and 65% relative humidity was performed. Samples were aged according to the standard ISO 5630:3 for 1, 2, 3, 6 and 12 days. Attention was focused on the investigation of the optical properties of papers (i.e. whiteness, opacity and yellowness) and colorimetric properties of CMYK prints during moist heat treatment. The properties of CMYK prints were determined with the measurements of CIELAB values before and after accelerated ageing and on the bases of those measurements the color differences have been calculated. The analysis revealed some deviations between CMYK prints and papers. The best durability upon accelerated ageing obtained the fiber synthetic paper and the black ink prints at all three types of paper.

Introduction

Ultraviolet (UV) cured printing is a fast growing area of printing which has many diverse applications. The UV inks are predominantly used in the printing on a variety of substrates, including a range of paper grades, high-grade card products, labels, metal, wood, fabrics, non-absorbent materials such as polyethylene (PE), polypropylene (PP), polyester (PES) etc. Ultraviolet ink systems contain photoinitiators which when activated with the correct wavelength radiation, will undergo a rapid free radical reaction causing the ink to set rapidly forming a dry, tough resin film. Curing prints using this system confers a number of advantages, namely rapid drying with no ink set off or smearing, high print gloss and an abrasion resistant surface. [1, 2]

The moist heat technique for accelerated paper ageing is slower and less effective compared to dry heat ageing, but better simulates the natural ageing behaviour of paper materials. [3] The light fastness of a print depends upon number of factors and, if not adequate, the color will fade, become dirtier or change shade and, eventually, the color can disappear altogether. These factors are the exposure conditions, time of exposure, substrate and ink film thickness, but primarily the colorants used. Resistance to fading or discoloration of color and durability of printed paper determine its suitability for outdoor applications. [4, 5]

This paper is focused on the investigation of the influence of accelerated ageing on the optical properties of special papers and also on the colorimetric properties of UV printed papers.

Methods and materials

Samples

In this study three types of special papers with approximately the same nominal grammage (100 g/m^2) were used: ***Paper 1***: *Neobond* (Neenah-Lahnstein Company, Germany), ***Paper 2***: *Catenelle* (Fabriano, Italy) and ***Paper 3***: *Small Money* (Gmund, Germany).

Neobond is a durable and hardwearing synthetic fiber paper. This double-side coated paper comprises a mixture of selected pulp and synthetic fibers (polyamide - PA, polyester – PES and viscose), which are reinforced by a special impregnation.

Catenelle is uncoated paper, made with 100% of E.C.F. chemical bleached pulp manufactured from tress. The pulp is woodfree and the stock doesn't contain ChemiThermoMechanical Pulp or ThermoMechanical Pulp. The paper has multitonal watermark and contains fluorescent security fibers.

Small Money is a woodfree paper, made from a mixture of old german marks, wastepaper and cellulose fibers.

Printing

Special papers were printed using a UV curable flatbed inkjet printer Océ Arizona 250 GT (piezoelectric inkjet using Océ VariaDot imaging technology, resolution: 1,440 dpi) and UV curable inks. A printing test form was prepared with CMYK solid colors.

Methodology

Unprinted and also CMYK printed papers were aged according to the standard SIST ISO 5630-3:1997: Accelerated ageing - Moist heat treatment at 80°C and 65% relative humidity for 1, 2, 3, 6 and 12 days.

On unprinted papers the difference in optical properties: CIE whiteness, opacity and yellowness E313 during accelerated ageing were determined (Spectroflash SF600 Datacolor International, measuring aperture: 2r = 6.6 mm).

Measurements of the L*a*b* values were made on CMYK printed papers before and after ageing using spectrophotometer Gretag Macbeth Eye-One (illumination: D50/2°, measurement geometry: 45°/0, measuring aperture: 4.5 mm). On the bases of those measurements, the difference in color (ΔE^*_{ab}), which appeared after ageing, have been calculated according to Eq. (1):

$$\Delta E^*_{ab} = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2] \quad (1)$$

where $\Delta L^* = L^*(0) - L^*(t)$; $\Delta a^* = a^*(0) - a^*(t)$; $\Delta b^* = b^*(0) - b^*(t)$ are differences calculated for original (0) ink films and the aged ink films (t).

Results and discussion

Accelerated ageing of papers

A specialty paper is typically a paper with a specific feature and must fulfil the criteria of having specific characteristics required for the specific use. One of them is synthetic paper. Synthetic paper is used in many applications where traditional cotton or pulp based paper will not long survive. One of them is outdoor application where the paper is exposed to the heat, rain and most particularly to the ultraviolet radiation. Another kind of a special paper is also a paper with fluorescent fibers, watermarks and other security elements included. Also for these papers higher resistance to heat, moisture, water and UV radiation is needed in order to last longer as ordinary printing papers. [6, 7]

In the first stage of the investigation, the optical properties of printing substrates (papers) during moist heat accelerated ageing were analyzed. The measured values of whiteness, opacity and yellowness for 0, 1, 2, 3, 6 and 12 days aged papers are presented in Figures 1, 2 and 3.

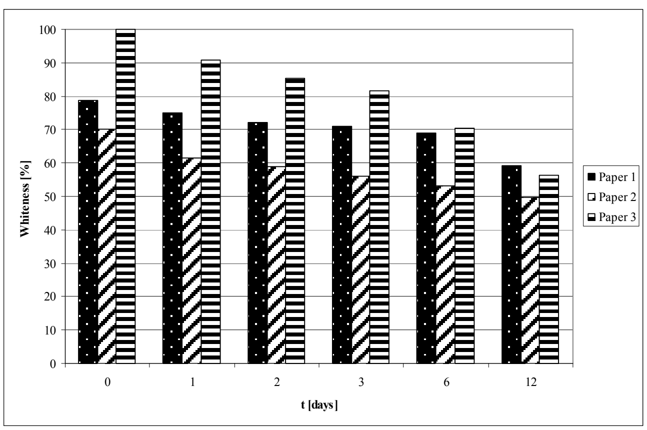

***Figure 1**: Difference in whiteness of papers during moist heat treatment.*

The influence of moist heat accelerated ageing of special papers has shown exponential decreased on whiteness with the time of ageing. Correlation coefficient is very high for all papers, values are around r_{xy} = 0.9067. According to the results, the unaged Paper 3 has the highest whiteness (100%), followed by the Paper 1 (78%) and the Paper 2 (70%). The whiteness of the Paper 1 droped for 19%, of the Paper 2 for 21% and of Paper 3 for 44% after 12 days of accelerated ageing. The Paper 3 exibited the lowest stability during ageing. In spite of its much higher value of whiteness before ageing, after ageing the whiteness of the Paper 3 was bellow 60%, similar as whiteness of other two analyzed papers.

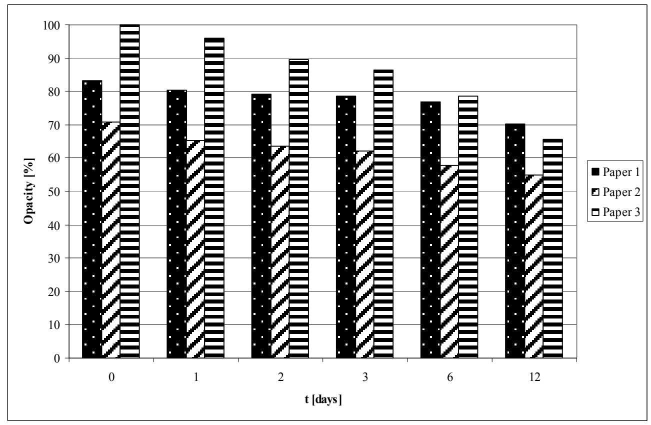

***Figure 2**: Difference in opacity of papers during moist heat treatment.*

As seen from the Figure 2, the unaged Paper 3 has also higher level of opacity (100%) compared to the Paper 1 (83%) and the Paper 2 (70%). The excellent stability of the paper`s opacity upon moist heat treatment was observed for the Paper 1, while the Paper 3 exhibited the lowest stability. In the case of 1 day moist heat treatment the opacity of the Paper 1 decreased for 3%, of the Paper 2 and Paper 3 for 5%, whereas after 12 days of moist heat treatment the opacity of the Paper 1 was lowered for 13%, of the Paper 2 for 16% and of the Paper 3 for 35%.

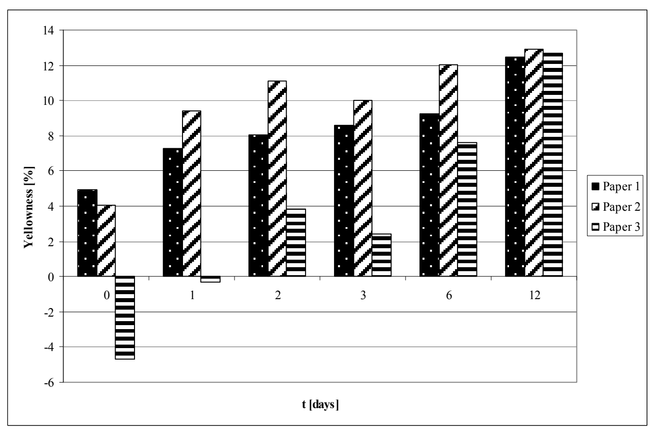

***Figure 3**: Difference in yellowness of papers during moist heat treatment.*

Paper yellowing is a natural process of paper ageing, which is caused by the sunlight, moisture, and the air. The loss of the brightness (paper yellowing) during the ageing procedure is attributed to the presence of the chromophores formed by the degradation of paper components (cellulose, hemicellulose, lignin). [3, 8] As can be seen from the Figure 3, the unaged Paper 1 and Paper 2 are yellowish, while the Paper 3 is more bluish (YI E313 = - 4.7). The yellowness during moist heat treamtment is more progressive at the Paper 2, though after 12 days of ageing, all three papers obtained approximately the same yellowness; up to YI E313 = 12.88. Yellowing of Paper 1 (r_{xy} = 0.7813) and Paper 2 (r_{xy} = 0.4076) exponential increased, meanwhile the Paper 3 demonstrated the polynomial increase (r_{xy} = 0.9467).

Accelerated ageing of CMYK prints on papers

The calculated color differences (ΔE^*_{ab}) of CMYK inks printed on all three papers after 1, 2, 3, 6 and 12 days of moist heat accelerated ageing are presented in Figures 4, 5, 6 and 7.

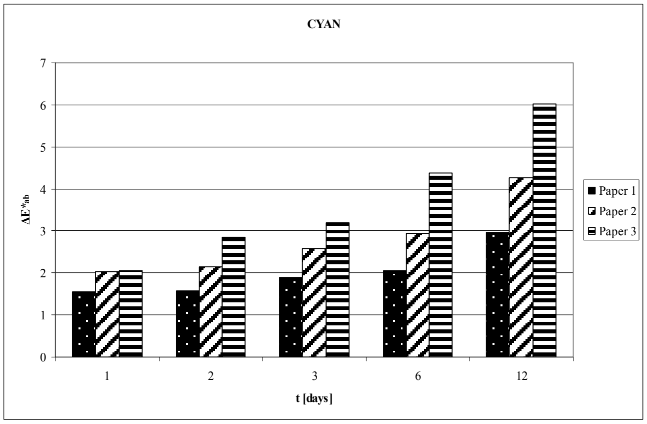

***Figure 4**: Color difference of cyan ink prints on papers during moist heat treatment.*

The moist heat treatment has influenced cyan ink prints on different papers, change in color was obtained. It is evident from the Figure 4 that the color difference (ΔE^*_{ab}) of cyan ink shows exponential increased with the time of ageing (approximately r_{xy} = 0.9470). The highest color differences, which correspond to the significant change in color, were obtained at the Paper 3. It started with the ΔE^*_{ab}= 2.05 in the case of 1 day of ageing, futhermore ΔE^*_{ab}= 2.84 (2 days), ΔE^*_{ab}= 3.19 (3 days), ΔE^*_{ab}= 4.38 (6 days) and ended with ΔE^*_{ab}= 6.02 (12 days). On the other hand the total color difference after 12 days of ageing of cyan ink prints on the Paper 1 was only ΔE^*_{ab}= 2.96, which corresponds to the negligible change in color.

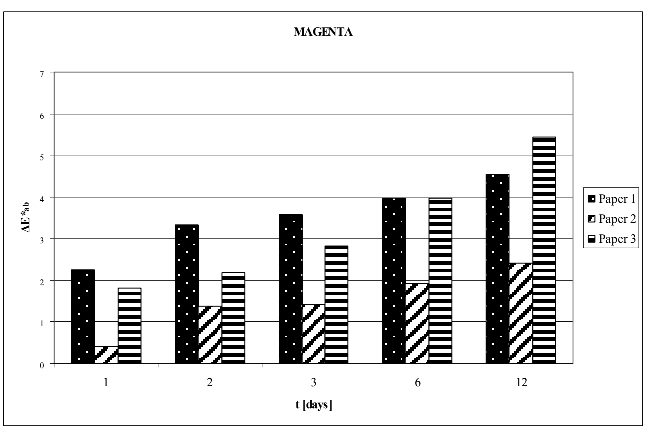

***Figure 5**: Color difference of magenta ink prints on papers during moist heat treatment.*

As shown in Figure 5 the magenta ink exhibited the highest durability at the Paper 2 and the lowest at the Paper 3. In the case of the Paper 2, the color difference hasn't exceeded the value of ΔE^*_{ab}= 2.40 after 12 days of ageing. On the other hand, the color difference of the magenta ink on Paper 1 was ΔE^*_{ab}= 4.54 and on the Paper 3 ΔE^*_{ab}= 5.45, that is a noticeable change in color.

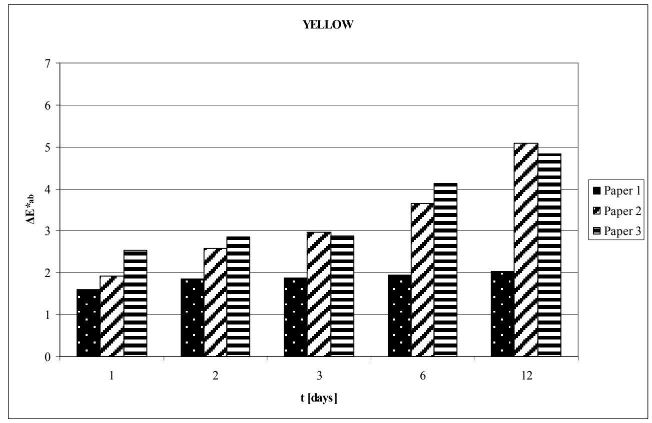

***Figure 6**: Color difference of yellow ink prints on papers during moist heat treatment.*

Figure 6 shows, that the color difference of yellow ink prints increases exponential at all three analyzed papers. On average the highest color differnece was obtained at the Paper 2. After 12 days of ageing the color difference was ΔE^*_{ab}= 5.08, which is clearly noticeable while the color difference of yellow ink prints at the Paper 1 hasn't exceeded the value up to ΔE^*_{ab}= 2.03.

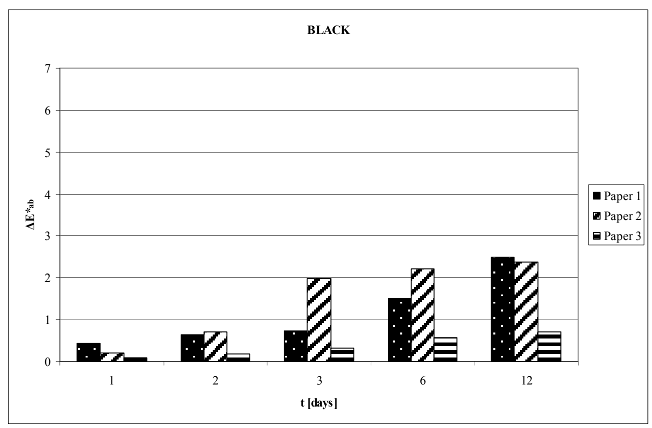

***Figure 7**: Color difference of black ink prints on papers during moist heat treatment.*

From the Figure 7 it is clearly seen that the color differences of black ink prints at all analyzed papers are very low. Correlation coefficient for all papers are approximately r_{xy} = 0.7132. After 12 days of ageing the color differences up to ΔE^*_{ab}= 2.48 (Paper 1), ΔE^*_{ab}= 2.36 (Paper 2), ΔE^*_{ab}= 0.71 (Paper 3) were obtained, which correspond to the negligible change in color.

Conclusions

In this study the moist heat treatment of unprinted and CMYK printed special papers made by UV ink-jet technology have been investigated. The results have shown that the lowest impact of moist heat treatment on whiteness and opacity of papers is seen at the Paper 1 (synthetic paper) and the highest at the Paper 3 (woodfree paper). After 12 days of ageing all three types of papers obtained approximately the same yellowness, although they had quite different color before ageing.

Color differences of CMYK ink prints increased exponential with the time of ageing. The best durability upon ageing was observed for black ink prints, where the change in color was imperceptible at all three analyzed papers. Cyan and magenta ink prints have shown the significant change in color at the Paper 3 and yellow ink prints at the Paper 2.

The best durability upon moist heat accelerated ageing was obtained for the fiber synthetic paper (Paper 1) and for black ink prints.

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Author Biography

Diana Gregor Svetec received her PhD in textile sciences from University of Ljubljan (1997). Since than she has worked as professor and researcher at University of Ljubljana, Faculty of Natural Sciences and Engineering. Her work has focused on characterization of properties of textile materials, printing substrates and packaging materials. She is editor-in-chief of scientific journal Tekstilec.

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