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Comparison Of Durability Between Uv Inkjet And Conventional Offset Prints Exposed To Accelerated Ageing

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Abstract:
The present study deals with the optical and colour stability of aged offset and UV inkjet prints. As a paper substrate, a film synthetic paper was used, which was printed by two techniques (UV inkjet press Óce Arizona 250® GT and conventional offset press KBA Performa 74). Film synthetic paper, offset prints and UV inkjet prints were artificially aged using standard techniques of accelerated ageing, such as moist-heat (80 °C and 65% relative humidity) and dry-heat (105 °C). Ageing was performed for periods of 1, 2, 3, 6 and 12 days. It was found that the moist-heat accelerated ageing influenced the most on optical properties of film synthetic paper. UV inkjet prints had higher colourfastness than the conventional offset prints. The most stable among all tested prints was the black colour UV inkjet print.

Key words: offset print, UV inkjet print, film synthetic paper, accelerated ageing, colourfastness.

Introduction

The printing inks represent a complex mixture of different components, which are classified by their function in ink matrix, and the ink composition is significantly dependent on the printing technology. The individual ink colours originate through the combination of the dye and pigments in the inks (Havlínová *et* al. 2002). The permanence of prints depends of its components and of the influence of the external factors (Bolanča *et* al., 2004). Generally, ageing could be in fact defined as a sum of all irreversible physical and chemical processes which happen in the material during the time. The durability depends mainly on the physical and mechanical characteristics of the raw materials, impact of microclimate factors such as heat, humidity or radiation and on contamination by ions and gas from the environment and action of microorganisms (Bolanča I. and Bolanča Z. 2004). The natural process of deterioration starts as soon as a colour image is printed, whether it is produced digitally or conventionally. Heat and moisture are two of the most important environmental influences on the stability of colour prints and papers. During an ageing procedure, the properties of paper materials and ink components can simultaneously change. High temperature and humidity adversely affect all colour print materials, although not to the same degree. Such elevated conditions cause the colours to deteriorate quite rapidly (Image Permanence Institute, 2007).

Just like all other organic materials, paper is also subjected to a number of fundamental deterioration processes (Porck, 2000). Deterioration in quality of an aged paper or prints can manifest itself in the physical mechanical, chemical and optical properties. The permanence of paper depends on the chemical resistance of its components and on the influence of external fac-

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tors. Discolouration of a paper may be caused by the formation of chromophores upon ageing as a result of exposure to light and volatile gases. Many volatile compounds as well as alcohols, ketones, aldehydes, carboxylic acids aromatic and aliphatic hydrocarbons and ethers can be released from paper during degradation processes depending upon paper chemical compositions (Gurnagual *et* al. 1993, Majnarič *et* al. 2010). Colour characteristics of inks used on such paper also change in time (Petkova *et* al. 2010).

Our main research interest is focused on the durability of UV inkjet and conventional offset prints, and also of film synthetic papers exposed to various methods of accelerated ageing. Previously published research considered mostly the durability of cellulose papers and conventional inks. The goal of our research was to estimate the durability of UV inkjet prints, conventional offset prints and synthetic paper for outdoor applications.

Experimental results

Printing

In this study, the conventional and digital printing technologies were used. Prints of solid CMYK colour fields were made by four colour offset press KBA Performa 74 with standard ISO 12647-2:2004 inking values and Sun Chemical mineral oil-free offset inks, while the digital prints were made on Óce Arizona 250® GT (UV Curable inks based on pigments) and on film synthetic paper Yupo (G=100 g/m^2). Paper Yupo is a biaxially-oriented film synthetic paper. It consists of three extruded polypropylene - PP layers with inorganic filler (Calcium Carbonate –$CaCO_3$).

Methodology

Film synthetic paper, offset and UV inkjet prints were aged using standard technique for accelerated ageing: *Moist-heat accelerated ageing* based on standard SIST ISO 5630-3 (80 ºC and 65 % relative humidity) and *Dry-heat accelerated ageing* based on standard SIST ISO 5630-1 (105 ºC) for 1, 2, 3, 6 and 12 days.

The optical properties of paper were evaluated based on the CIE Whiteness and Yellowness Index YI E313. The measurements were made with a spectrophotometer Spectroflash 600-Datacolor International (D65 standard illumination, 10° standard observer, D/0 measurement geometry and measuring aperture: 2r=6.6 mm).

The CIE formula is based on the calculation of X, Y, Z values. It takes into consideration both lightness and chromaticity of white samples. The CIE Whiteness, based on the standard ISO 11475, is defined as:

$$W = Y + 800(x_0 - x) + 1700(y_0 - y) \quad (1)$$

where W is the CIE Whiteness, Y is the tristimulus value of a white sample and x and y are the chromaticity coordinates of the white sample.

The Yellowness Index, according to the ASTM Method E313, is calculated as follows:

$$YIE313 = \frac{100(C_X X - C_Z Z)}{Y} \quad (2)$$

where X, Y, Z are the CIE trismilus values, and C_X and C_Z are coefficients (D65/10º: $C_x = 1.3013$, $C_Z = 1.1498$).

The colourimetric properties of the solid CMYK prints were determined using a spectrophotometer, Gretag-Macbeth Eye-One (D50 standard illumination, 2º standard observer, 45/0 measurement geometry and 4.5 mm measuring aperture). The colour differences (ΔE^*_{ab}), which appeared after ageing, were calculated according to Eq. (3):

$$\Delta E^*_{ab} = \sqrt{(\Delta L)^{*2} + (\Delta a)^{*2} + (\Delta b)^{*2}} \quad (3)$$

where $\Delta L^* = L^*(0) - L^*(t)$;

$\Delta a^* = a^*(0) - a^*(t)$;

$\Delta b^* = b^*(0) - b^*(t)$

are the differences calculated for the not aged (0) prints and the aged prints (t) (Thompson, 1998).

Results And Discussion

SEM analysis

Figure 1 present the SEM images of the not aged surface topography of film synthetic paper, black (K) offset print with 20% tone value and black (K) UV inkjet print with 20% tone value.

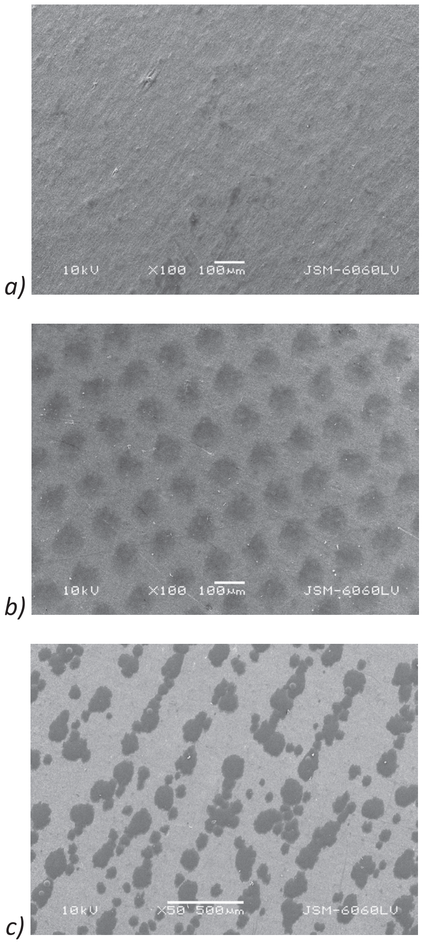

Figure 1: SEM images of unaged surface topography: a) film synthetic paper, b) black (K) offset print with 20% tone value and c) black (K) UV inkjet print with 20% tone value.

In the scanning electron image of film synthetic paper the smooth and even surface can be observed. The paper Yupo is smoother than most typical base papers. It doesn't contain wood pulp or other bio materials and has a penetration layer on both sides. The comparison between the black (K) offset print with 20% tone value and black (K) UV inkjet print also with 20% tone value, some differences are seen. At conventional offset print (Figure 1/b), the raster dots are evenly spaced due to AM halftoning algorithms, meanwhile at UV inkjet print (Figure 1/c), a uniform tone coverage can be seen obtained by FM halftoning of raster dots.

The influence of accelerated ageing on the optical properties of film synthetic paper

Synthetic printing papers are defined as products composed of at least 20% synthetic substances. These papers have a well-developed surface capable of absorbing printing inks, a coefficient of maximum ink absorption of at least 50%, and the capability of fixing the printing inks, even those with low adhesiveness to the base paper (Paszkowska *et* al., 2005). Synthetic papers are generally divided according to their manufacturing method into two broad categories: film synthetic paper and fibre synthetic paper (Yupo Corporation, 2008). Fibre synthetic paper is manufactured from synthetic materials in the form of spun bonded fibres with an effectively infinite length or short fibres that are added to pulp, meanwhile a film synthetic papers is a product made from granulated materials formed by extrusion in the form of a biaxial oriented multilayer paper (Paszkowska *et* al., 2005). The greatest benefit of synthetic paper is its durability under almost any conditions (Ducey, 2003).

Figure 2 shows the influence of accelerated ageing on the optical properties of film synthetic paper.

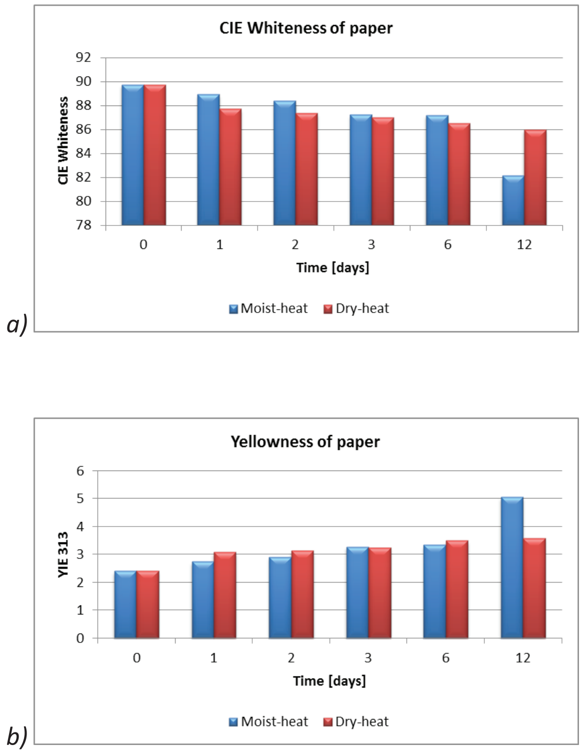

Figure 2: The influence of accelerated ageing on optical properties of film synthetic paper: a) CIE Whiteness of paper and b) Yellowness of paper.

The deterioration of paper upon ageing is initiated by the irreversible change of their mechanical, chemical and optical properties. As seen from Figure 2/a, the most pronounced influence on CIE Whiteness of paper has moist-heat accelerated ageing. Values of CIE Whiteness dropped after 12 days of moist-heat ageing from 89.8 to 82.1, meanwhile at dry-heat ageing the values dropped to 86.0. Furthermore the yellowness of paper (Figure 2/b) extreme increased during moist-heat ageing. The unaged paper's Yellowness Index was YI E313=2.4. After 12 days of moist-heat ageing, the Yellowness Index exponential increase to value of YIE313=5.1. Paper yellowing is a natural process of paper ageing, which is caused by sunlight, moisture, and air. The whole complex of these factors and their impact on paper is called photochemical ageing (Havlínová *et* al., 2002).

The influence of accelerated ageing on offset prints

There are two basic types of pigment used in offset printing inks. Organic pigment, which is made from carbon, is used for making black ink. Inorganic pigments, which are made by mixing various chemicals together, are used for coloured inks (sulphur, silica, china clay) (Offset Inks, 2002).

Figure 3 shows the influence of accelerated ageing on CMYK offset prints.

Significant differences between CMYK offset prints were noticed during accelerated ageing as we can see from Figure 3. Dry-heat accelerated ageing (105 °C) was much more progressive for cyan and magenta offset print, meanwhile the moist-heat accelerated ageing (80 °C and 65 % relative humidity) for yellow and black offset print. After 12 days of dry-heat ageing the colour difference at cyan offset print reached value of ΔE^*_{ab}= 4.9 and at magenta offset print value of ΔE^*_{ab}= 5.9, which corresponds to noticeable change in colour. It was noticed, that yellow offset print was the most durable after both accelerated ageing, where the values was below 3.1 after 12 days of ageing. Black offset print was also durable during dry-heat ageing, meanwhile at most-heat ageing the colour difference reached the value of ΔE^*_{ab}= 5.6 after 12 days.

The influence of accelerated ageing on UV inkjet prints

Inkjet prints vary widely not only in the compositions of their colorants and paper but also in their stability (Image Permanence Institute, 2007). Ultraviolet curing inks have a different structure than conventional printing inks. They are made up of monomers, prepolymers /oligomers, pigments/colorants, additives and photoinitiators/synergists. One of the advantages of UV inks is the high light fastness of the UV cured films (Debeljak and Gregor-Svetec, 2010).

Figure 4 shows the influence of accelerated ageing on CMYK UV inkjet prints.

It was established that UV inkjet prints were more durable in comparison to offset prints made with mineral oil free based printing inks. Higher colour difference obtained only on yellow UV inkjet print, where the colour differences after both accelerated ageing reached value up to ΔE^*_{ab}= 5. Dry-heat accelerated ageing was the most progressive for all CMYK UV inkjet prints. After 12 days of dry-heat ageing the colour differences reached for cyan UV inkjet print the value of ΔE^*_{ab}= 4.2, for magenta UV inkjet print the value of ΔE^*_{ab}= 5.5, for yellow UV inkjet print the value of ΔE^*_{ab}= 5.2 and for black UV inkjet print the value of ΔE^*_{ab}= 2.0. The dry-heat ageing procedure is very powerful and fast. Three days under these conditions correspond to 25 years of natural paper ageing. On the other hand, the moist heat technique of accelerated ageing of material

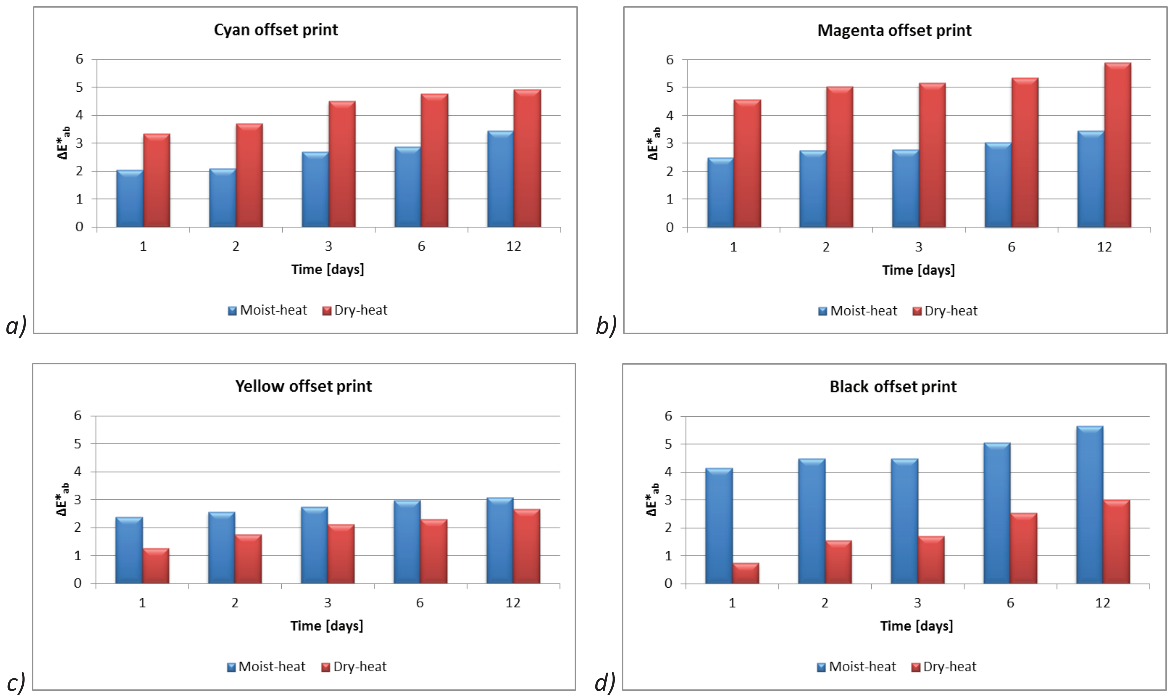

Figure 3: The influence of accelerated ageing on offset prints: a) cyan, b) magenta, c) yellow and d) black.

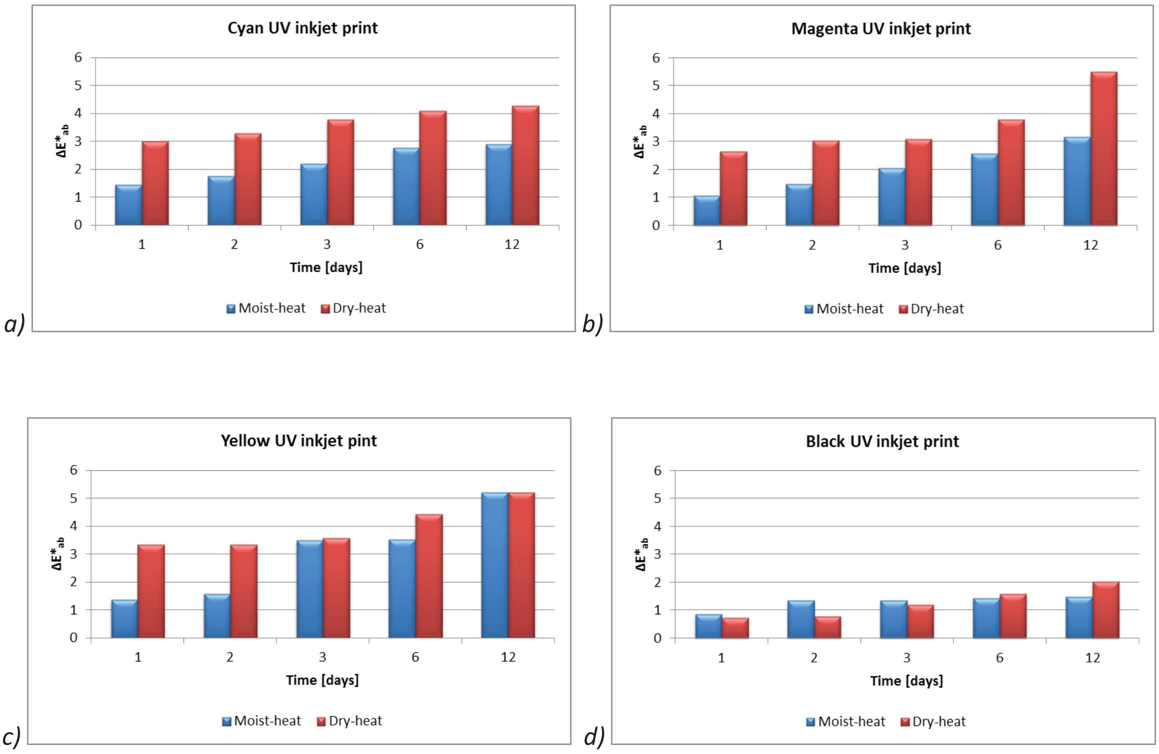

Figure 4: The influence of accelerated ageing on UV inkjet prints : a) cyan, b) magenta, c) yellow and d) black.

is slower and less effective, but simulates the natural ageing behaviour of materials better. Moist-heat treatment at 80C and 65% relative humidity for 24 days is commonly believed to be equivalent to 100 years of natural ageing (Havlínová *et* al., 2002). Pigmented inks are known to have better stability than dye-based inks because of their crystalline structure (Vikman, 2003). Black UV inkjet print was very stable for both techniques of accelerated ageing. The colour differences didn't exceeded a value of 2, which corresponds to negligible change in colour.

Conclusions

The results obtained during processes of accelerated ageing indicated that CIE Whiteness of film synthetic paper decreased and Yellowness Index increased. The application of moist-heat accelerated ageing (80 °C and 65 % relative humidity) caused the most obvious degradable influence on optical properties of film synthetic paper. Significant colourfastness differences between aged offset and UV inkjet prints were noticed. It was established that moist-heat ageing influenced the most for cyan and magenta offset print, meanwhile the dry-heat ageing influenced the most for all CMYK UV inkjet prints. UV inkjet prints were more stable than conventional offset prints, especially black UV inkjet print.

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