Ageing of substrate and the quality of digital prints

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Abstract

Deterioration in quality of an aged paper or prints can manifest itself in chemical permanence and the decrease in mechanical durability. In this work the colorimetric characteristics of digital prints (digital offset printing Indigo, Xerox, Ink Jet) made on wood free natural paper in relation to the process of accelerated ageing have been presented. Non aged substrates, aged substrates, prints on non aged paper, aged prints, and prints on aged paper have been analyzed. The results obtained by the FT-IR spectroscopy and relevant values essential for the reproduction qualities have been discussed in the work.

Introduction

Generally, ageing of paper could be in fact defined as a sum of all irreversible physical and chemical processes which happen in the material during time.

Deterioration in quality of an aged paper can manifest itself in chemical permanence and the decrease in mechanical durability [1]. The permanence of paper or prints depends on the chemical resistance of its components and of the influence of external factors [2]. It includes light fastness and points at resistivity of the printing ink against fading and colour change after exposition to light [3].

The durability depends mainly on the physical and mechanical characteristics of the raw materials, impact of microclimatic factors such as heat, humidity or radiation and on contamination by ions and gas from the environment and action of microorganisms [4-6].

The Duponts studied the ageing behaviour of gelatine used to size paper. Results showed that gelatine undergoes hydrolysis upon ageing and the result was an increase in the lower molar mass fractions [7]

Exposure of paper to very short wavelength ultraviolet (254nm) radiation induced post-irradiation effect, which influenced internal and external factors [8]. The result of exposure to visible and ultraviolet radiation of paper is its discoloration effects during and after exposure. The aim of Bukovski`s report is to consider the share of the short-term daylight action with partly reduced UV radiation that induced oxidation degradation of groundwood paper in the presence of various amounts of the secondary chromophores, formed in the paper itself [9].

The adsorption of sulphur dioxide by paper as the atmospheric pollutant depends on many factors [10]. Temperature affects SO_2 absorption. The increase of SO_2 absorption with increasing temperature is not high, based on kinetics of chemical reaction. Transition of metal ions present as soluble salts may increase the sulphur dioxide absorption too. The influence of papermaking additives on SO_2 absorption by paper is noticed. Papers containing rosin, alum size, calcium carbonate or mechanical pulp pick up more sulphur dioxide. Atmospheric ozone treatment can enhance the strength properties of the mechanical pulp.

Natural ageing process of paper and prints causes the degradation of cellulose The presence of moisture, oxidative agents and microorganisms is important in this process and especially the presence of acidic substances. The results in this case are the hydrolysis of cellulose that appears in shortening of its chain along with changes in content of crystalline form [11]. Short term irradiation of paper initiates light induced oxidation reactions, which continues even after paper is stored in the dark [12].

Discolouration of a paper may be caused by the formation of chromophores upon ageing as a result of exposure to other light and volatile gases [13]. 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.

Acid catalyzed hydrolysis of cellulose was recognized to be the primary reaction of the accelerated deterioration of paper. For study of accelerated ageing of paper new methods are being developed and recently a mathematical model was presented for temperatures from Rychlyet at al.[14].

Colorimetric characteristics of the non aged papers, aged paper, Xerox, Indigo and Ink Jet prints on non aged paper, aged prints, and prints on aged paper have been presented in this work. Relevant values essential for the reproduction quality as well as the results obtained by the FT-IR spectroscopy have been discussed.

Experimental

Indigo E-print 1000+ and Xerox DC 50 digital printing machines as well as Epson photo1200 Ink Jet printer were used for printing. The printing form contains different printing elements: multicolour halftone images, patches for determining the colour densities, halftone values, relative printing contrast, trapping patches, patches for determination the dimensional stability, colour register control, areas for determination of grey balance and standard wedge.

The printing was done on wood-free natural paper (Acroprint EW, Fedrigoni): grammage $100 g/m^2$ and thickness 0,120 mm.

Determined series of substrates and prints were accelerated aged in climatic chamber under the following conditions: temperature 80^0C, relative humidity 65% and ageing time 24 days without the influence of radiation.

In the experimental part three series of samples were comprised: prints on non-aged paper, prints on aged paper and aged prints, as shown in figure 1.

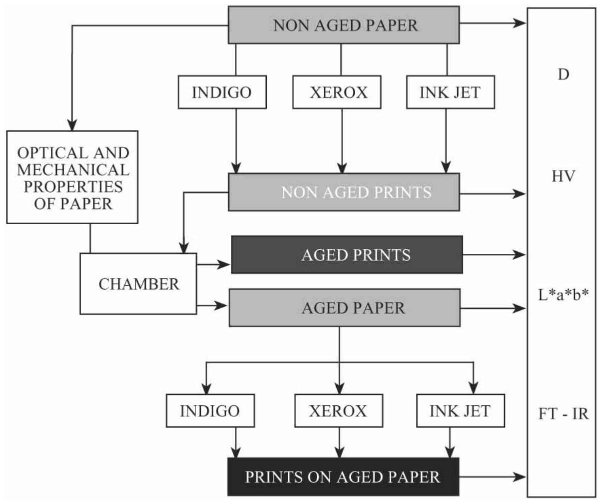


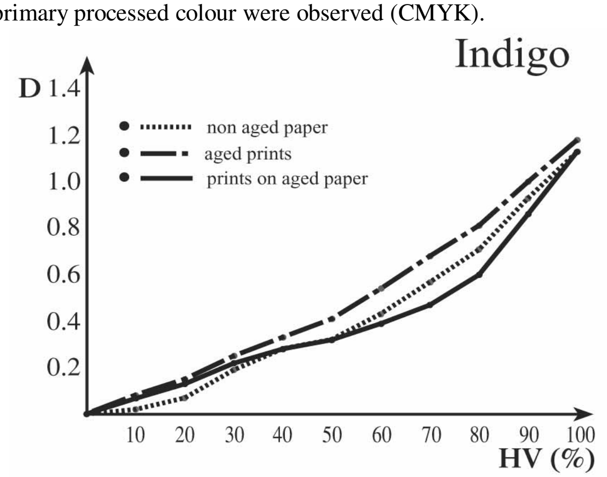
Figure 1. *Diagram of the experiment workflow*

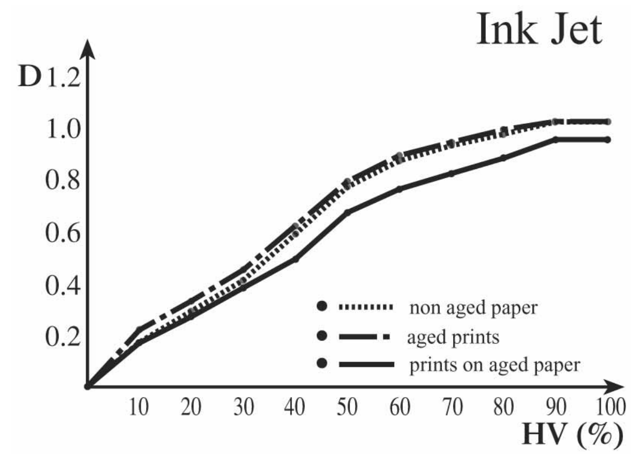
Optical parameters for description of series samples were performed by X-Rite spectrophotometer with the support of ColorShop program. The measuring results were processed by means of Data Analysis program and technical Graphic Origin Professional. Except that, the spectrophotometer Datacolor Elrepho 450X was also used.

For monitoring the products of paper degradation FT-IR spectroscopy was used. The straightforward transmission technique was used. Samples processed by FT-IR spectarum were made in the form of pastil from paper and KBr. By using the Spectrum One Perkin Elmer spectrometer the spectra in the area of 4000-400 cm^{-1} were taken with the peak intensities from 0-100% transmission.

Results and discusion

It is possible to follow the reproduction quality by the relationship of print colour density and halftone value of the original, halftone value of the original and original and by determination the relative printing contrast. From the extensive researches in this area, graphs are chosen for the presentation that show the relationship of the colour density and halftone value for Indigo, Xerox and Ink Jet prints for yellow only, although all the primary processed colour were observed (CMYK).





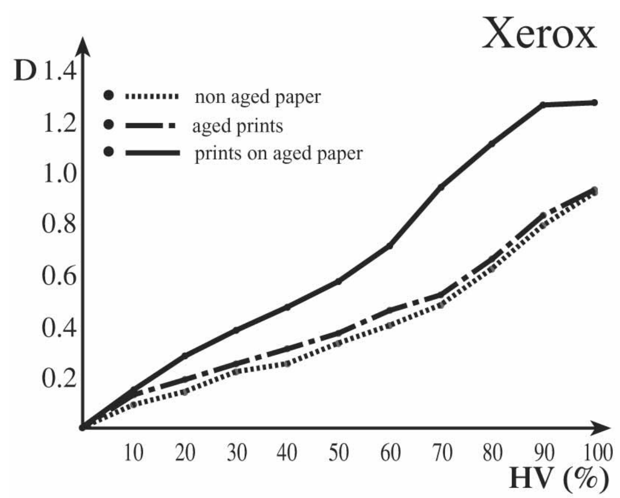


Figure 2. *Relationship of the colour density and halftone value*

In yellow Indigo print one can notice greater aberration of the colour density within the areas between 60 and 90% HV for prints on aged paper. At 80% HV the yellow oscillates for D_{80} 0, 20. Aged Xerox prints do not show the noticeable difference. Xerox prints on aged paper show greater aberrations in relation to the ones made on non aged paper. On yellow print the inking densities grow with the increase of halftone value. The greatest aberration is at 80% screen, where the colour density is D_{80} 0,48. The curves of dependence of the colour density and the halftone value show the following considerable characteristics on prints made by Xerox technique. The print on non aged paper and the same print after ageing do not show essential differences and have in this part similar behaviour as the prints of Indigo technique. However the prints on aged paper considerable vary from the prints on non aged paper. Ink Jet prints on aged paper in the area between 30 % and 100% HV have reduced colour density. It varies greatly from the halftone value of D_{60} 0,08.

Figure 3 presents the results of spectrophotometric measurements of cyan, magenta and yellow in full layer of ink.

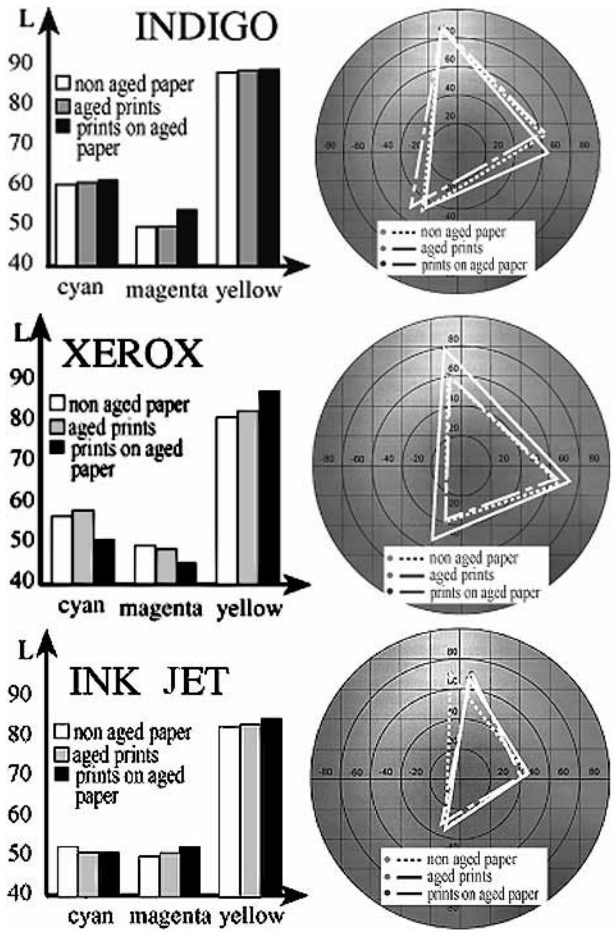
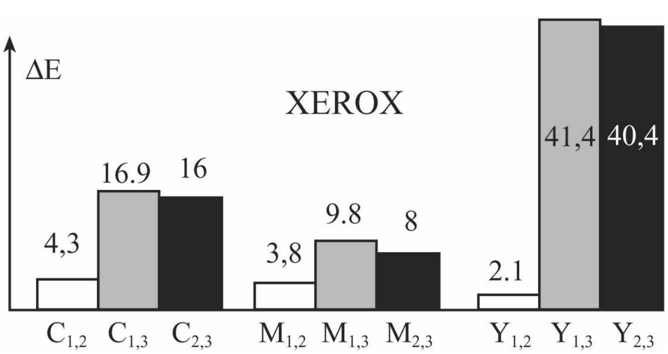


Figure 3. *Influence of accelerated ageing on L*a*b* values*

Aged Indigo prints completely coincide with the non aged paper u yellow area. Smaller positive aberrations exist within the blue area. Prints on aged paper have greater tone change and increased area of reproduction. The ageing process of the printing substrate has almost no influence on lightness on Indigo prints. The lightness of Xerox prints changes with ageing, while the chromatic aberrations are very big. On Ink Jet the influence of paper ageing is recognizable.

The ink stability of print by ageing can be monitored with colour difference ΔE, and the obtained results are presented in figure 4.



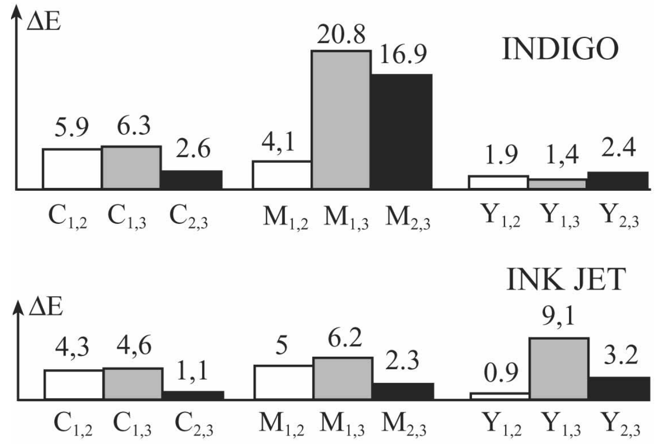


Figure 4. *The ageing influence on the colour difference*

These results confirm the already presented statements that the stability of colour depends on the optical characteristics of the printing form, on ink type and on printing process.

By ageing of Indigo prints greater differences in inking - color difference $\Delta E_{1,2}$ for CMY cannot be noticed. However the prints on aged paper in relation to the prints on non aged paper as well as on aged prints have the greatest difference in $\Delta E_{1,3}$ 15,7 and $\Delta E_{2,3}$ 13,5 on magenta prints.

On Xerox prints by ageing there are not considerable changes of colour difference. The changes in colour density appear mostly on prints on aged paper in relation to the prints on non aged paper $\Delta E_{1,3}$ C 16,9, M 9,9 Y 41,4. The greatest values for yellow print are obtained for the prints on aged paper in relation to the aged yelow prints $\Delta E_{2,3}$ 40,4.

By accelerated ageing of ink Jet prints the following color difference $\Delta E_{1,2}$ C 4,4, M 5,0 Y 0,9 appear. In this case the yellow print stays alsmot unchangeable. The aged prints and prints on aged paper do not greater aberrations either.

In order to obtain more detailed insight into the changes of the stability of the printing substrate in relation to the accelerated ageing process, its mechanical and optical properties were observed .The investigation results show that smaller decrease of resistivity to spraying, inconsiderable decrease of absorbency, and considerable decrease of double folding appear by ageing of paper.

In table 1 the colorimetric values of the non aged and aged paper are presented.

Table 1. Colorimetric characteristics of the non aged and aged paper

Sample	L*	a*	b*	ΔE
Non aged paper	94,56	3,96	-8,83	2,3
Aged paper	93,88	2,89	-4,73	

By ageing the printing substrate, the determined stability is noticed. Inconsiderable changes in brighter and darker, as well as the shift in red-green and yellow-blue coordinate are noticed. Generally, the increase of b* value is credited to the chromophores which appear by degradation of the paper components such as cellulose, chemicellulose and lignin.

In figure 5 FT-IR spectra are presented in the wavenumbers from 4000,0 to 400,0 cm^{-1} for non aged printing substrate and accelerated aged substrate with the aim of determining the influence of optical properties change which can originate from degradation in the ageing conditions.

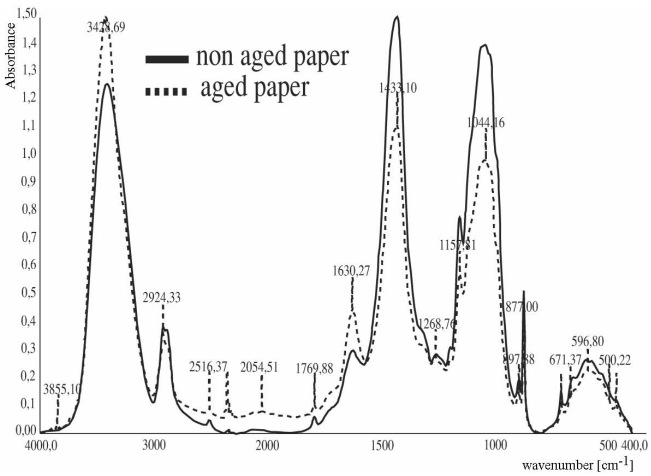


Figure 5. *FT-IR spectra of aged and non aged paper*

As it is visible from the results on the aged paper the increase of absorbency in FT-IR spectra near 1600 cm^{-1} appears which corresponds to increasing the intensity of carboxyl peak and which is the result of oxidation processes caused by ageing. Carboxyl groups have somewhat smaller effect on decreasing the optical properties of the aged paper in relation to the carbonyl ones, however they increase their effect. At oxidative degradation of the low molecule part of the carbohydrate, carbonyl groups appear which influence the decrease of brightness and the increase of yellowness of paper, and the complex changes can be noticed at the wavenumber 1734 cm^{-1}, for which the vibrations C=O are responsible. By increasing the temperature and the relative humidity the described changes appear which corresponds to the microclimatic conditions of the accelerated ageing.

At the other hand, such printing substrate was chose for printing which contains low concentrations of heavy metals, which gives greater optical stability of paper, because the photo-catalyctic activity and absorbency in UV area is characteristic for heavy metals, which decreases the brightness and increases the yellowness.

Conclusion

Based on the research results it can be concluded that the Indigo aged prints show greater stability in relation to other techniques. On Xerox prints on aged paper, greater aberrations appear on some colours in relation to the prints on non aged paper. On Ink Yet prints quick closing of screen appears and the prints on aged paper do not reach the values of those made on non aged paper. In the experimental conditions the results show that Indigo print with higher quality is possible on aged papers.

This work in the scientific sense is the contribution to the explanation of the problem of the reproduction ageing in digital printing including the relevant parameters of the reproduction process from the point of view of formal characteristics of the printing substrate. The results application can contribute to the improved reproduction objectivity.

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Biography

PhD Zdenka Bolanca is the professor and head of the Department for Ecological Engineering at the Faculty of Graphic Arts, University of Zagreb. She lectures several courses on graduate and postgraduate study. She published about two hundred scientific papers. The area of her scientific investigation is industrial ecology, recycling of paper, and the mechanisms of paper ageing and stability of prints.

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