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Durability of Ink Jet prints

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Abstract. The aim of this paper is the result presentation of some optical properties research for ink jet prints after: exposing the prints to the mixed daylight and artificial light, exposing of prints to the sun-light through the glass window, and exposing of prints to outdoor conditions during the summer months.
The prints obtained by piezoelectric and thermal ink jet technologies were used in the researches. The dye-based inks and the pigmented inks based on water and the low solvent inks were used.
The results of these researches, except the scientific contribution in the domain of understanding and explaining the environmental conditions on the gamut size, i.e. the range of color tonality, colorimetric stability and print quality, can be used by the ink and paper manufacturers in new formulations, offer data for the printer producers for further production and evaluation of the position of their products.

1.Introduction

Image quality, durability and storage stability are three major attributes of ink jet prints that attract attention and have driven a continuous improvement in this technology over the past years.

Durability of color prints has steadily improved. Improvements have targeted the following areas: lightfastness, thermostability, water-fastness, humidity-fastness, and pollution gas-fastness [1, 2]. Light fastness is one of the most important items in ink jet printing [3].

Degradation of dyes as it is known depends on a wide variety of environmental parameters like temperature, humidity, light intensity and spectral distribution. Pigment based inks have better resistance to gas and light and better water-fastness than dyes [4]. A lot of researches and empirical explanations known in the literature describe how dye degradation may take place and which the most probable degradation mechanisms are. Previous work with dye- based inks showed that the light fading of cyan and magenta were media dependent. Thermal dye transfer prints have poor image stability when exposed to visible or ultraviolet light or subjected to heat because of the inherent chemical properties of dye molecules [5].

Ozone is known as a very aggressive substance and it belongs to the most powerful known oxidants. Many researches were done to understand the mechanism of the ozone oxidation of dyes [6]. Ozone itself, or the decomposition product singlet oxygen, is believed to be the active species in the oxidation process of organic compounds. Other pollution gases like NO_x and SO_2 are also considered to be aggressive agents, but they seem to play only a minor role in the gas fading phenomenon of colorant [1].

De Rossi and coauthors present research of activation energies on different media with different dyes also considering the influence of room humidity [7].

The purpose of this paper is the result presentation of the gamut research of ink jet prints exposed in the air-conditioned room with mixed daylight and artificial light and exposing the prints to the daylight radiation through the glass window in summer months. The prints obtained by piezoelectric and thermal ink jet technologies were used in the researches. The dye-based inks and the pigmented inks based on water and the low-solvent inks were used. The results of these researches, except the scientific contribution in the domain of understanding and explaining the environmental conditions on the gamut size, i.e. the range of color tonality and print quality, can be used by the ink and paper manufacturers in new formulations, as well as for further production and evaluation of the position of the products.

2. Experimental

Ink jet technology is the printing technology using the ink droplets without the contact with the printing substrate. The ink droplets are sprayed through the nozzles on the substrate to obtain the image.

The prints obtained by piezoelectric and thermal ink jet technologies were used in the research. The following printers were used: Epson Stylus PRO 7000, HP Designjet 9000s and HP Designjet 500.

Epson stylus PRO 7000 has Micro Piezo DX3 printing heads which achieved the high quality prints. Maximal resolution is 1440 x 720 dpi. Six dye based inks (cyan, magenta, yellow, black, light cyan and light magenta) were used.

HP Designjet 9000s uses piezoelectric ink jet technology. The resolution of printing is 720x720 dpi. Six printing heads were used for printing CMYK + C_L + M_L, the same as in the previously described printer. This printer uses carbon filters to absorb the air volatile organic compounds released during the printing process. The system is designed to absorb VOC from air at rates consistent with the print speed and number of compounds released during printing. Low-solvent inks were used for printing.

HP Designjet 500 uses color thermal ink jet technology. Maximal printing resolution is 1200x600 dpi. CMYK water -based ink jet inks were used.

The test form contained ISO and ECI patterns. The part containing the ECI measuring form consists of fields with different combination color values of the subtractive synthesis. It was intended for spectrophotometric analysis. The information quantity obtained by such measurements enabled the construction of 2D and 3D gamut in perceptual uniform color space. ISO illustration was printed for the visual control.

Some of the important paper for ink jet printers properties made are smoothness, gloss and penetration. The mirror reflection of the incoming light appears on the smooth paper surface and the diffuse reflection which is not good for the print quality, appears on the rough surface. Except that, this printing technique demands from the substrate the equableness of the penetration angle in order to prevent the side ink spilling. The coated papers (matt and glossy) are characterized by better mechanical and chemical surface properties which influence the interaction with the ink and its better adherence. Solstar matt paper, declared as the poster paper for indoors and outdoors graphics, was used for printing (substrate1). It can be used in combination with dye-based and pigmented inks, oil, eco/mild solvents.

Many office papers were processed for the usage in ink jet and laser printing technology. Paper (substrate 2) was intended for printing based on electrophotography – laser printing. Because of that, it has special importance in comparison with the substrate 1 in the described experimental conditions.

The prints are divided into three series. In the first series the samples were exposed in the air-conditioned room to the mixed daylight and artificial light in the duration of 1 and 2 months. The samples in the second series were exposed from the inside of the room through the glass window in the duration from 1 to 3 months during the summer period. In the third series prints were exposed to outdoor conditions during the summer months.

After that, the instrumental analysis comprised the measurements made by spectrophotometer, followed by the statistic data processing obtained by measurements of each field. Except that, the conversion from CIEXYZ into CIE L*a*b* system was performed in order to enable the presentation of 3D gamut of samples in the three-dimensional unified color space. The presentations were made at the level L* equals 60. FT-IR spectrophotometer Spectrum One Perkin Elmer was used.

3. Results and discussions

Information distribution depends on different media which have limited information quantity that they can present. Information refers mainly to those concerning the threestimulus value transformation of the determined color. Gamut represents the total range of information on color, i.e. tone, saturation and lightness which can be reproduced by the given medium. Gamut limits present the volumes or surface which is determined by the gamut extremes.

For objective evaluation of the print quality the ECI values of field samples of different combinations of color values of the subtractive synthesis were measured and the values for the construction of 3D color cubic units were obtained by the computer support and conversion.

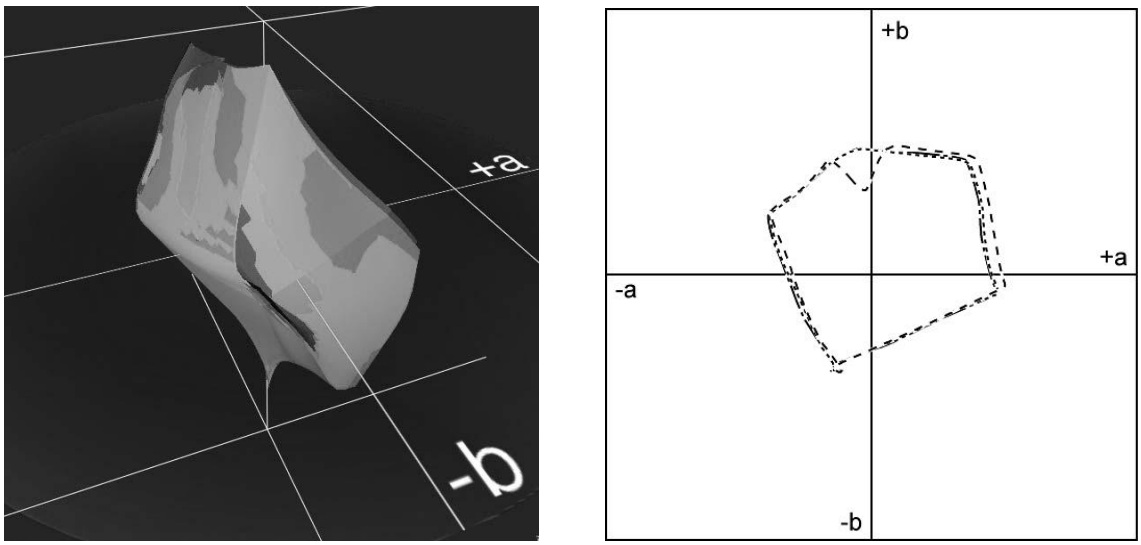


Figure 1. Print gamut 3D and 2D (HP DesignJet 500,sample 1, series 1)

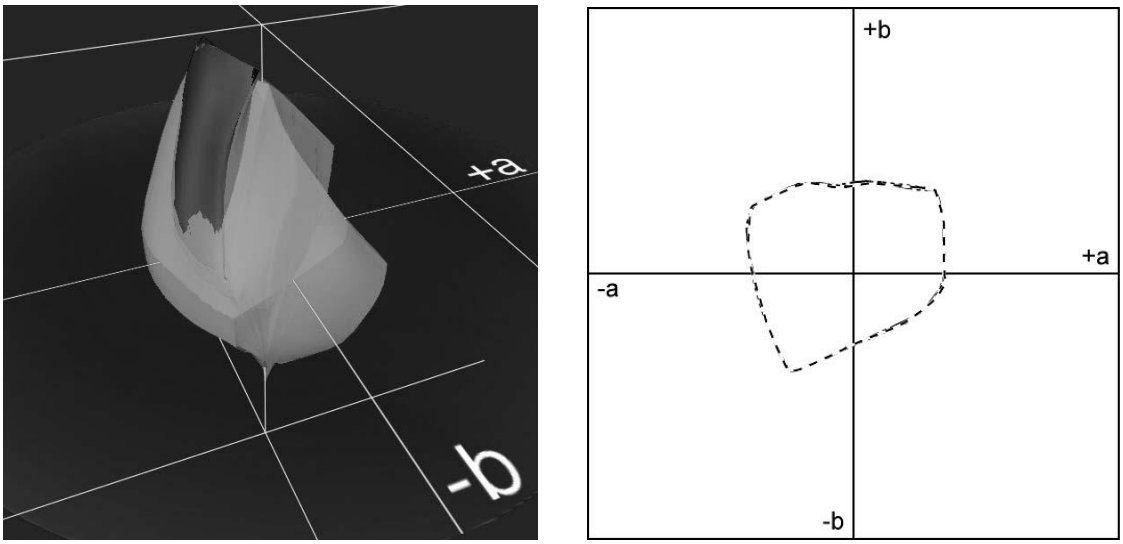


Figure 2. Print gamut 3D and 2D (HP DesignJet 500, sample 2, series 1)

Table 1. Volumes of gamut V CIE L*a*b* CCU (HP DesignJet 500, series 1)

	Before exposure	Exposure 1 month	Exposure 2 months
Sample 1	370553	362984	368766
Sample 2	282024	280554	282082

The samples exposed in the air-conditioned room with the mixed daylight and artificial light in the duration of 1 and 2 months almost did not show the volume change of gamut. The print on the substrate 2 had smaller gamut for 88529 units, which resulted in lower print quality. In sample 1 the gamut changing caused by print ageing were visible in the area of magenta and orange.

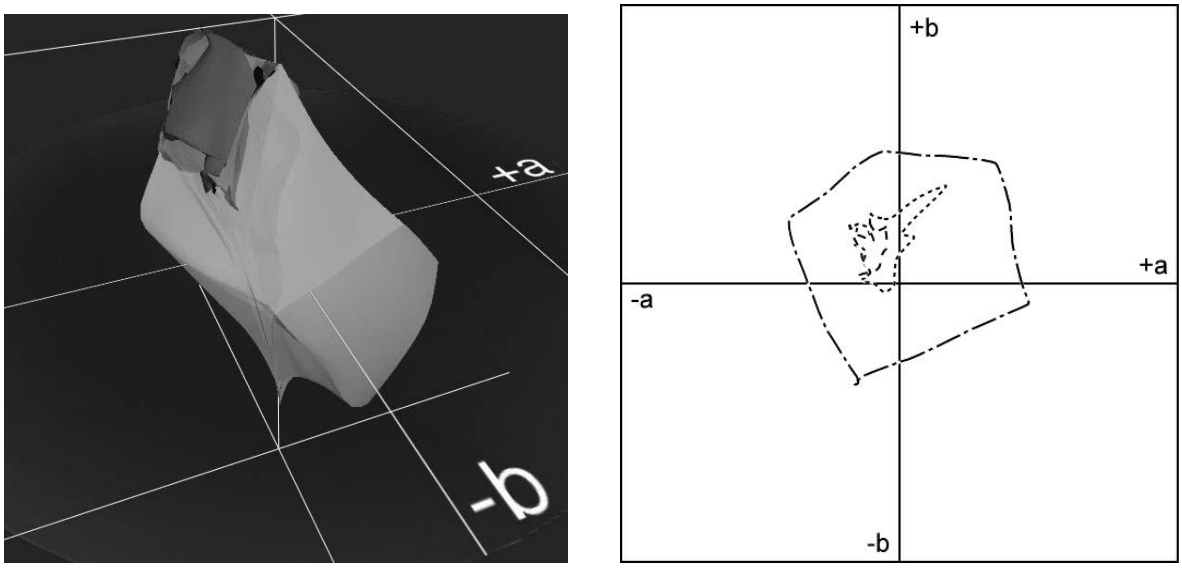


Figure 3. Print gamut 3D and 2D, (HP DesignJet 500, sample 1, series 2)

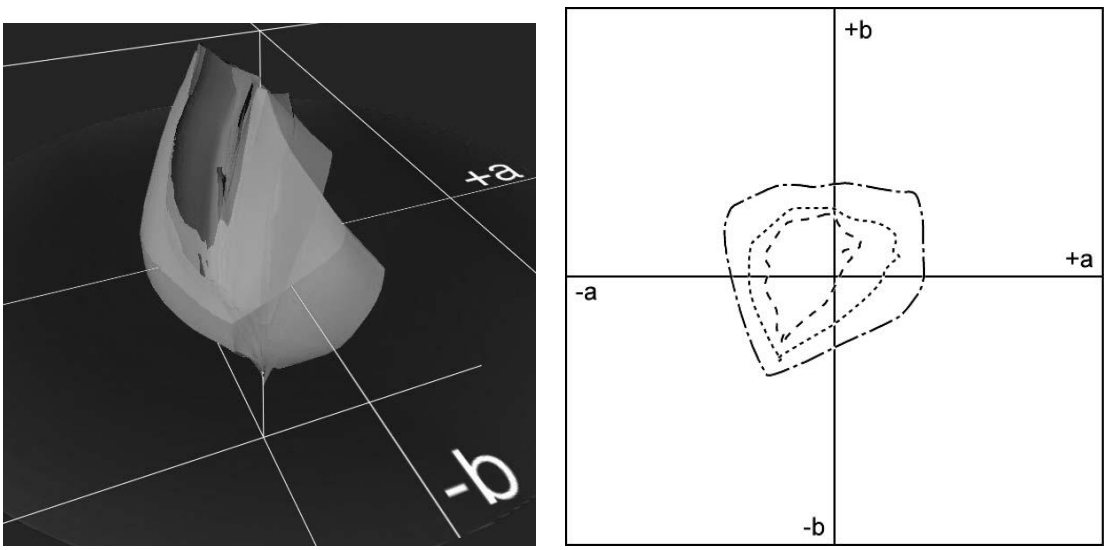


Figure 4. Print gamut 3D and 2D (HP DesignJet 500, sample 2, series 2)

Table 2. Volumes of gamut V CIE L*a*b* CCU (HP DesignJet 500, series 2)

	Before exposure	Exposure 1 month	Exposure 2 months
Sample 1	370553	114717	54848
Sample 2	282024	171098	113186

The samples of the second series were exposed from the inside of the room through the glass window in the duration from 1 to 2 months during the summer period. On the sample 1, after 1 month exposure the gamut volume decreased for 255836 gamut units.

In the second month the influence of print exposure was much smaller and the gamut volume decreased for 59869 units. The decrease of gamut volume was noticeable in all color areas.

When exposing the print through the glass window the gamut volume decrease is noticeable for 110926 units after one month on sample 2 and for further 57912 units after two months. In this case greater changes are visible in the red area.

In figures 5 and 6 the gamuts for prints exposed to outdoor conditions during the summer months are presented. The general weather characteristics were the high air temperatures and sunny weather without greater street level air streaming. From the air pollution source the intensive traffic had to be excluded which pointed at the presence of pollutants, among others oxygen, nitrogen and ozone, which had previously been determined to be the gas fading phenomenon of colorant.

For the print on the substrate 1 the gamut volume decreased for 334352 units, i.e. for 90.23% for exposing it to outer conditions in the duration of one month (figure 5). The trend of gamut decrease continued in the second month but with considerably smaller intensity. The gamut volume decreased for 18419 units or for 49.91%.

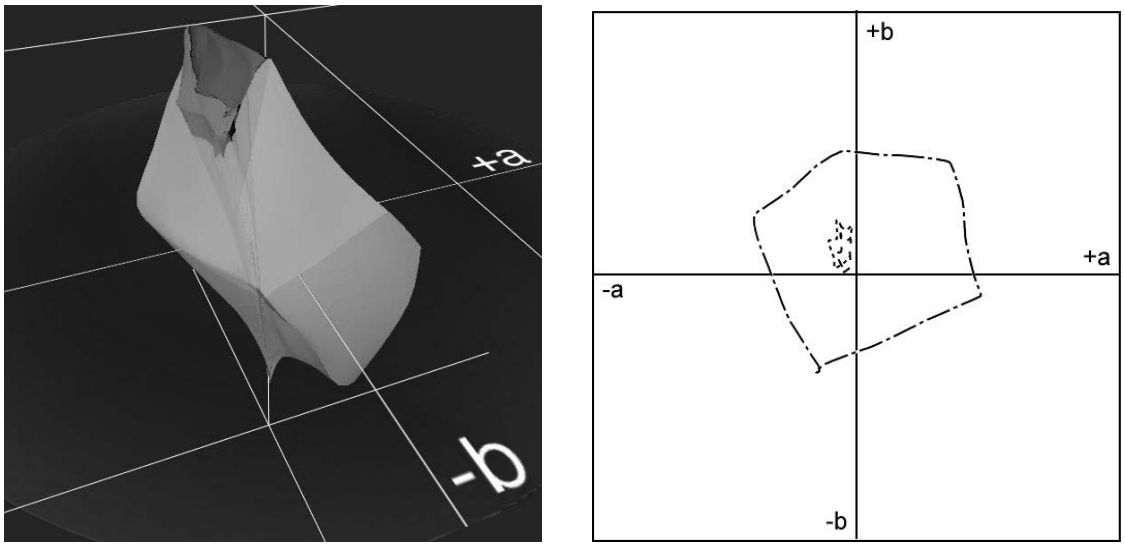


Figure 5. Print gamut 3D and 2D (HP DesignJet 500, sample 1, series 3)

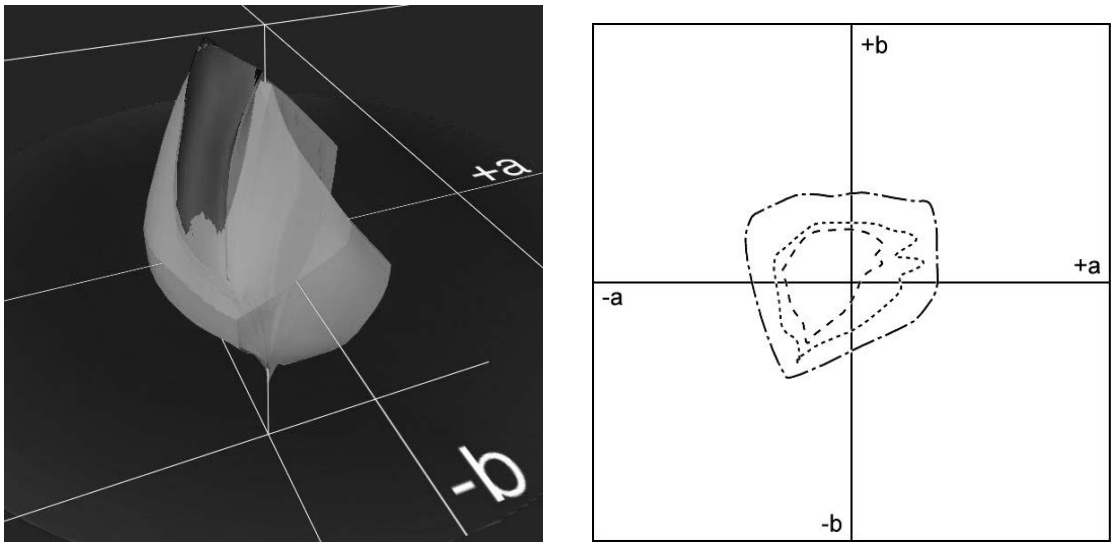


Figure 6. Print gamut 3D and 2D (HP DesignJet 500, sample 2, series 3)

Table 3. Volumes of gamut V CIE L*a*b* CCU (HP DesignJet 500, series 3)

	Before exposure	Exposure 1 month	Exposure 2 months
Sample 1	370553	36201	18419
Sample 2	282024	164485	119850

On the print on the substrate 2 the influence of the environment was even smaller (figure 6). In the first month of exposure the gamut volume decreased for 117539 gamut units or for 41.68%. After exposure in the second month the print gamut decreased for only 27.14%. The results point at the influence size of the ink interaction with the printing substrate on the print stability in the described experimental conditions using the pigment ink for the sample preparation.

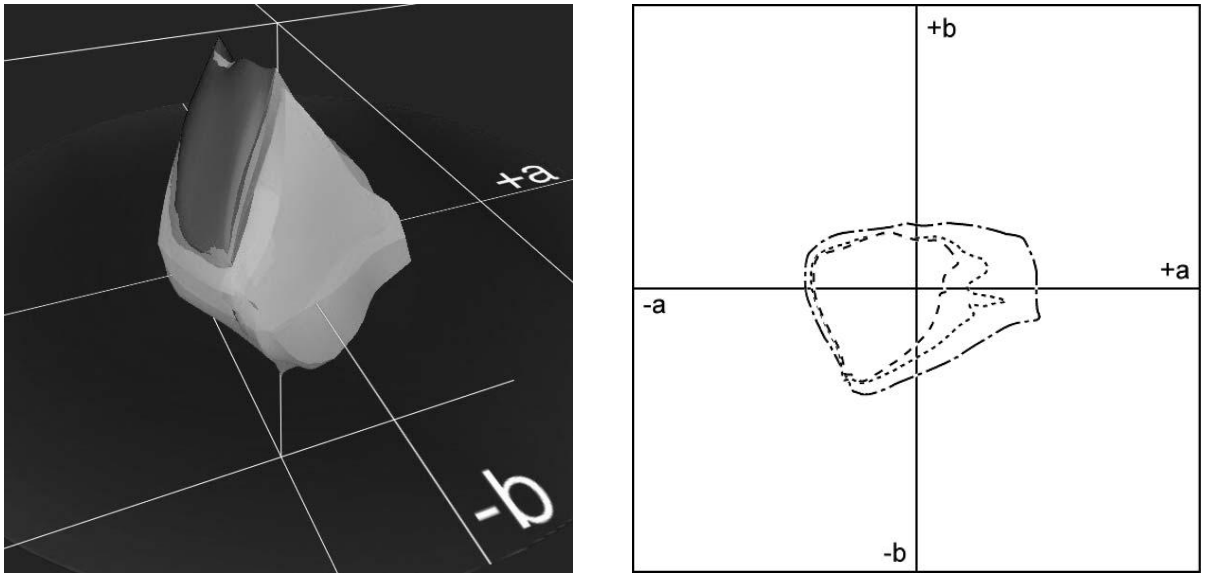


Figure 7. Print gamut 3D and 2D (Epson stylus PRO 7000, sample 2, series 3)

In figure 7, 3D and 2D print gamuts were presented for using the Epson stylus PRO 7000 and six dye based inks under the same criteria of exposure to the outdoor conditions as presented for series 3. In this case far greater durability of print was obtained. After the first month exposure the volume of gamut decreased for 41.68%, and in the second one for 27.14%. The results undoubtedly show that in the application of pigment as well as the dye based inks, in the first month of exposure conditions greater influence, i.e. the prints were less stable regarding the exposition continuation.

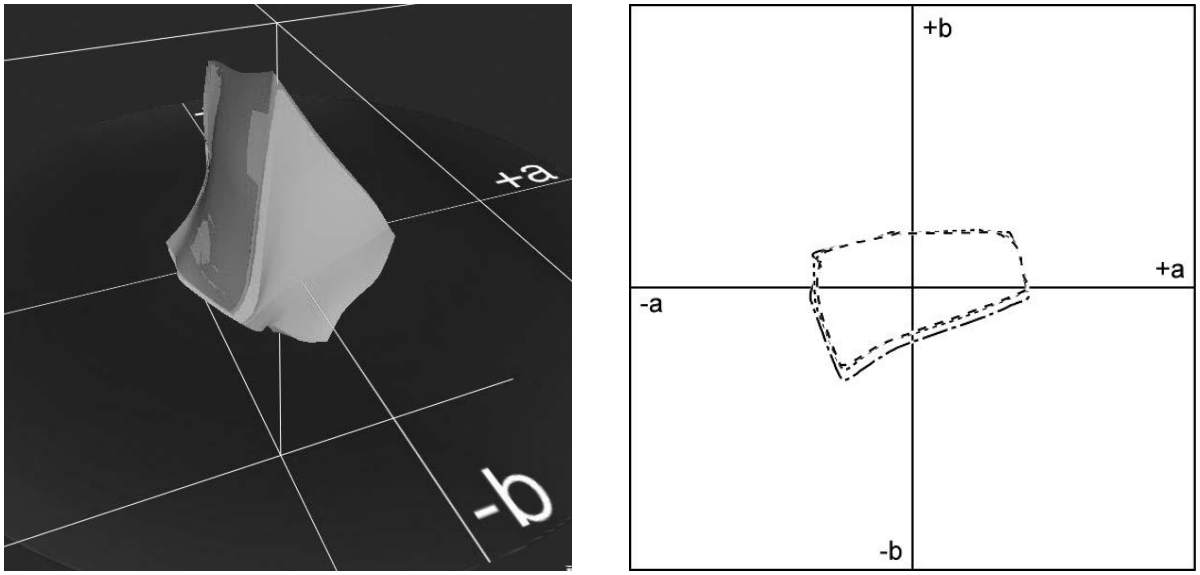


Figure 8. Print gamut 3D and 2D (HP DesignJet 9000s sample 2, series 3)

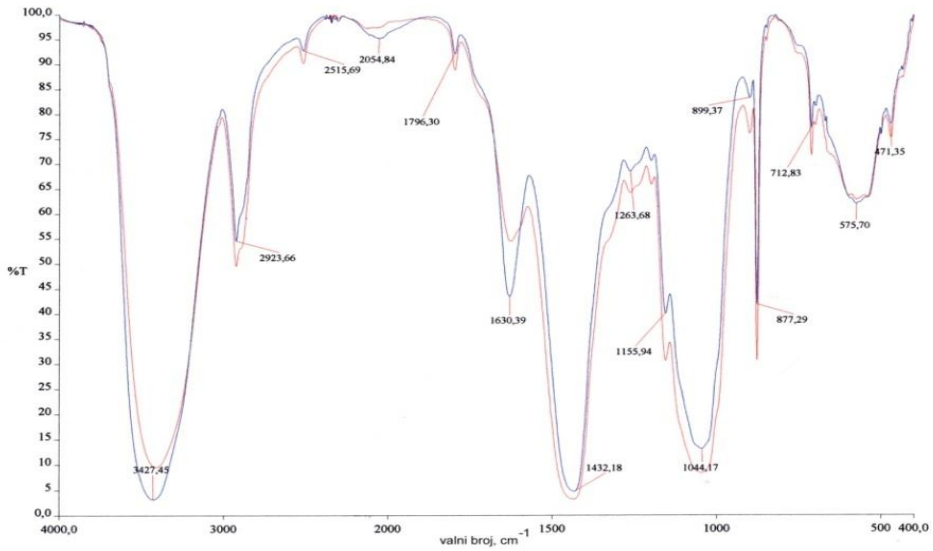
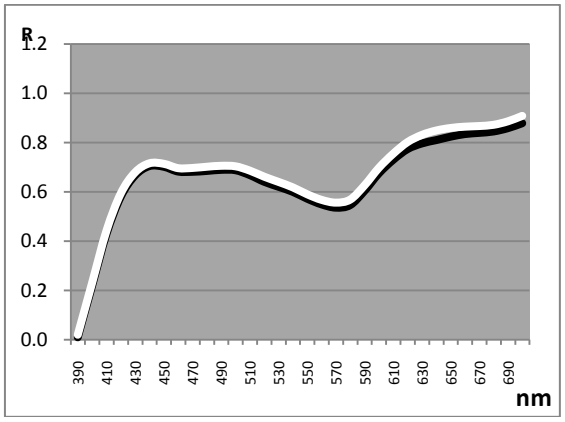


Figure 9. Compared FT-IR spectrum of the sample 2 (unexposed ------. exposed ------)

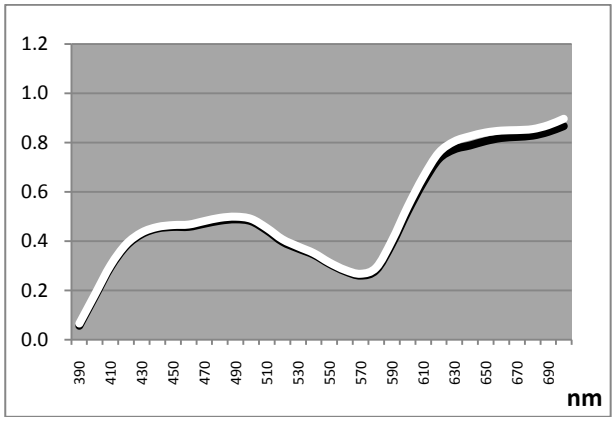
In the first month of exposition greater influence of the exposure conditions appear for the dye based inks, i.e. the prints are less stable.

In studying of prints stability, it is interesting to include the stability of the print and the substrate. In figure 9, the comparative FT-IR spectra of the sample 2 before and after exposure are presented. The change in the intensity of the characteristic peaks of these two spectra is obvious. The intensity difference of planar vibration of the connection which can be caused by the exposure conditions is noticeable. Somewhat greater absorption in the area from 1200 – 1000 cm^{-1} characteristic for C-O stretching appeared.

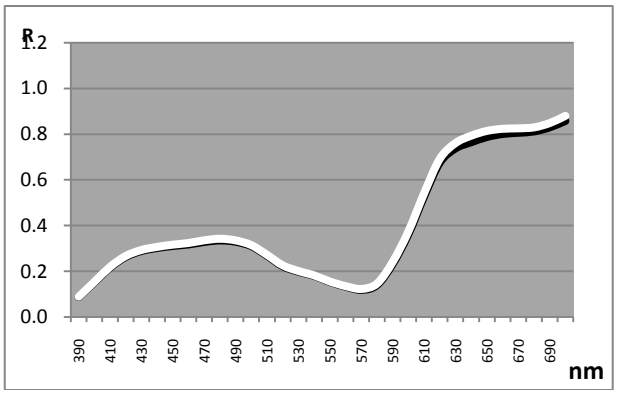
However, for explanation of the problems the information which originates from the interaction of the substrate and the determined ink in the function of the exposition conditions is important. The reflection curves in the area of wave lengths from 390 – 700 nm for the unexposed and the exposed print using the HP DesignJet 500 and Epson stylus PRO 7000 for sample 2 and series 3 (figure 10) are presented.



20% screen value

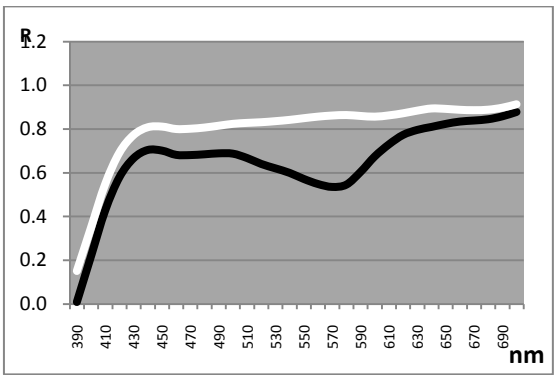


50% screen value

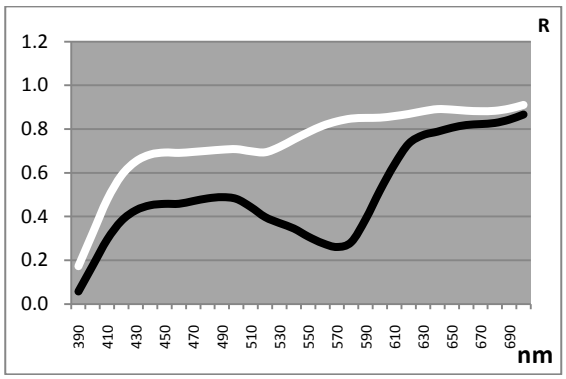


80% screen value

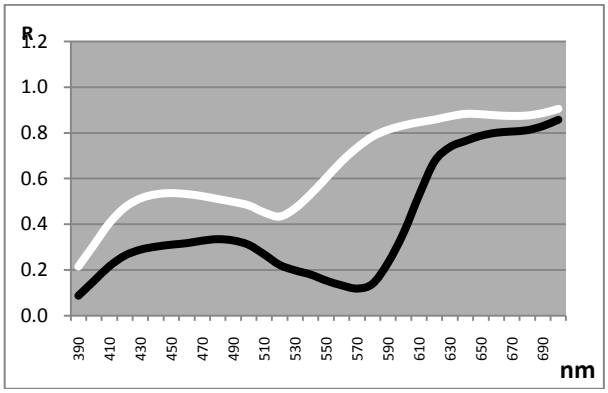
HP DesignJet 500, sample 2, series 1



20% screen value

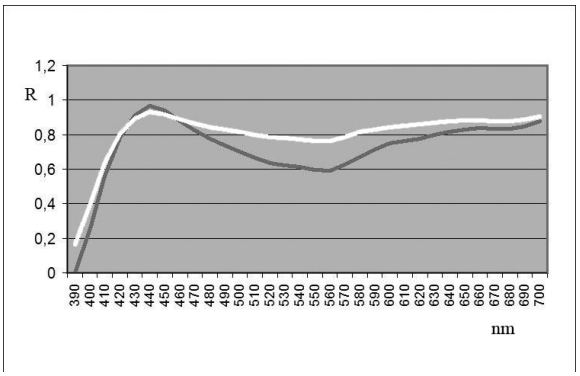


50% screen value

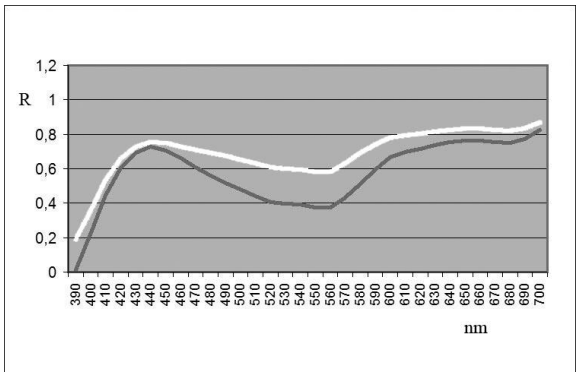


80% screen value

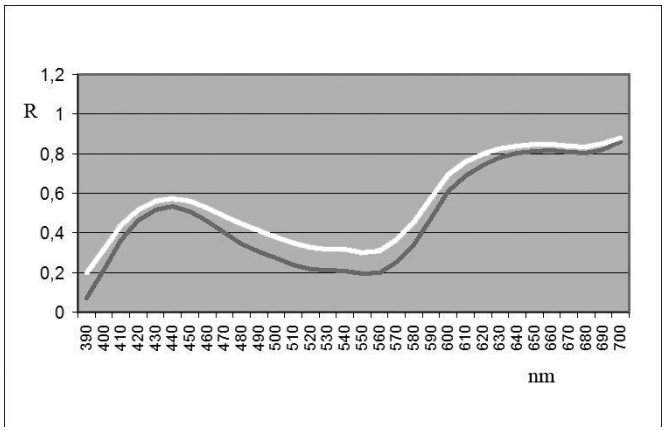
HP DesignJet 500, sample 2, series 3)



20% screen value



50% screen value



80% screen value

Epson stylus PRO 7000, sample 2, series 3

Figure 10. Reflectance spectra of the prints with magenta (20%, 50% and 80% screen value)

In reflectance curves for 20% screen value the reflection was increased in the area of shorter wave lengths (violet – blue spectrum part) which was caused by the addition of optical whitening agents in the printing substrate. By the increase of screen value, the influence of the substrate was slowly

decreased and the rapid fading of magenta was noticed by exposing the sample to the outdoor conditions where the kind of inks in combination with the printing substrate became prominent.

The obtained results of the researches, presented here only in one segment, could be explained by the mechanisms which include photooxidation/reduction of the chromophores. Such mechanisms are especially important in the case of azo colorants. The rapid shift of adsorption peak at 560 nm could be noticed in magenta in the presented spectrum. This is the reason of colorant modification.

4. Conclusion

Based on the results the following conclusion can be made:

- On prints obtained with the printer HP DesignJet 500, the exposition in the air-conditioned room to the mixed daylight and artificial light in the duration of 1 and 2 months almost does not influence the volume of gamut .
- Print on the substrate 2 has smaller gamut for 23.89 units in relation to the sample 1. By exposing the print on the substrate 1 through the glass window in the duration of 1 month during the summer period the gamut is decreased for 69.04%, and for the print on the substrate 2 it decreases for 39.33%. By prolonging the exposition period for another month the influence of the exposition conditions on the volume of gamut is lesser for about 14-24% depending on the substrate.
- For prints exposed to outdoor conditions during the summer months in the duration of one month, gamut is decreased from 49. 91 to 90.23% depending on the used printing substrate.
- Far greater stability of print is obtaine by using the dye based inks in relation to the pigments in combination with the printing substrate.
- From the reflectance spectra of the prints with magenta (20%, 50% and 80% screen value) the rapid shift of the absorption peak at 560 nm can be noticed which influences the modification of colorant and which is explained by the mechanism of chromophores photooxidation.

Except the scientific contribution in the domain of understanding and explanation of the environment conditions and the size of the print gamut which reflects on their quality the investigation results have the applicative character. The application of the results can be in the area of new formulation of the graphic materials in the area of InkJet technique as well as in the development of the test methods for the influence of dry time on performance of InkJet print, and the prints stability, which will be the continuation of these investigations.

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