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RESEARCH OF THE INFLUENCE OF DIGITAL PRINTING ON THE OPTICAL INDICATORS OF IMPRINTS OF PHILATELIC PRODUCTS 'ON DEMAND'

The article presents the results of research on the optical indicators of digital printing on marks paper. Based on the results of a visual evaluation of test imprints obtained on all types of equipment selected for the study, it was established that jet printing technology and UV printing are not suitable for forming images on gummed stamp' paper. Based on the results of the research, it can be concluded that the researched gummed paper is quite suitable for the execution of individual personalized orders by electrographic printing.

Keywords: digital printing method; gummed stamp' paper; quality assessment; optical indicators of imprints; digital printing defects.

Introduction

One of the types of accidental products is philatelic products (postage stamps and blocks, envelopes, postal cards, etc.). This direction is gradually gaining special importance both in Ukraine and abroad. Philatelic products are bought not only to pay for postal services or replenish one's own collections, but also to make an original gift.

The 'Own label' service from Ukrposhta company has gained popularity in Ukraine. This is an opportunity to make a stamp sheet, envelope or postcard with your own design. Not only individuals, but also companies apply for this service. So, for example, the Monobank company ordered its own brand from Ukrposhta company for further use in marketing.

But since the circulation of such products is not always in the thousands or millions, the actual task is the possibility of manufacturing stamp' products in small and single editions.

Thus, there is a need to determine the optimal type of digital printing, which can most effectively ensure the production of personalized stamp' and philatelic products in single or small editions. This will contribute to the development of the philately segment in both souvenir and advertising directions.

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The classic technology for manufacturing post stamps is offset printing. However, stamp printing to order is small runs or single orders. Therefore, the question arises of finding a digital printing technology that can ensure printing on gummed stamp' paper and achieve quality indicators close to offset imprints.

In the article [1] experimental studies of the quality of tone reproduction of digital printing machines were carried out by comparing the gradation curves of the toner image obtained on papers of different thicknesses. In [2] study, the tested papers were treated with different dyes, which resulted in the change of the paper's optical properties, but not surface roughness. The print density was impacted by the paper whiteness and ISO brightness. The effect of the paper whiteness on the print density is a stronger linear correlation compared to the ISO brightness. Paper whiteness has a positive correlation with the ISO brightness. The print colorimetric values (lightness and chroma values) increased with increasing paper whiteness up to a certain level, after which the paper whiteness did not have a noticeable impact on its print lightness and chroma values. The print color (a* and b* values) was affected by its corresponding paper color. In the article [3] represented paper properties, that are one of the most important factors affecting the completeness of the image transfer and image appearance. It affects print contrast, colour reproduction and surface uniformity. This paper were to goal to better understand the impact of optical paper properties (whiteness, brightness and opacity) on colour reproduction in digital printing as well as on the human perceived print quality. In this study, ten different uncoated and coated papers were used. As results suggest, unlike opacity, whiteness and brightness of paper are in correlation to perceived print quality.

In [4] study, the goal, were to better understand the impact of optical paper properties (whiteness, brightness and opacity) on color reproduction in digital printing as well as on the human perceived print quality. In this study, ten different uncoated and coated papers were used. A visual assessment of the printed samples was carried out in order to relate the influence of the optical paper properties to perceived color reproduction quality under different light sources. As results suggest, unlike opacity, whiteness and brightness of paper are in correlation to perceived print quality. In the article of Yang Y., Gao Q., Liu Q. [5] investigated paper surface efficiency (PSE), a paper property integrating gloss and absorbency, can be used to evaluate color reproduction after the interaction of paper and ink. But it was shown that the color reproduction was still related to paper whiteness in practice. In this paper, an assumed PSE formula which integrates gloss, whiteness and ink absorbency is firstly presented, and according to experimental data, it can be well forecasted that the change of these principal paper properties would affect color reproduction result via the new PSE formula.

Many other researchers were engaged in the issue of researching the quality of imprints on vari-

ous materials, in particular in the research of digital printing. However, the question of the quality of digital printing on gummed stamp' paper is relevant.

Methods

Equipment for digital printing on the market of Ukraine today is represented by a large number of printers and printing machines of various configurations, which work according to various printing technologies. Among the digital technologies used for printing on paper and cardboard, laser and inkjet are the most common. The market of digital equipment also includes equipment that works with sublimation and solid ink technology. However, such technologies are much less popular due to a smaller range of applications compared to laser or jet technologies.

The purpose of the work is to study the quality indicators of imprints obtained on stamp' paper using various digital printing technologies; establishing, based on the results of a comparative study, recommendations regarding the choice of technology for printing single editions of stamps.

To carry out the research, marked sheets, which are currently offered by Ukrposhta company for the fulfillment of personalized orders, were selected. There are several variants of marked sheets with coupons of 6, 9 and 28 stamps. Chalked gummed stamp paper weighing 102 g/m^2, format 220×154 mm (a sheet of 9 stamps, fig. 1) was chosen for the research. To evaluate and compare the color indicators of the control fields, printing was also carried out on offset and coated papers weighing 80 g/m^2.

To achieve the specified goal of the work, it is necessary to develop a test form that will take into account all the features of layouts that are inherent in branded products. So, the test form was developed based on the requirements of the standard [6] and the quality indicators defined for the assessment of imprints obtained by the digital printing method [7–10]. The test form was developed in

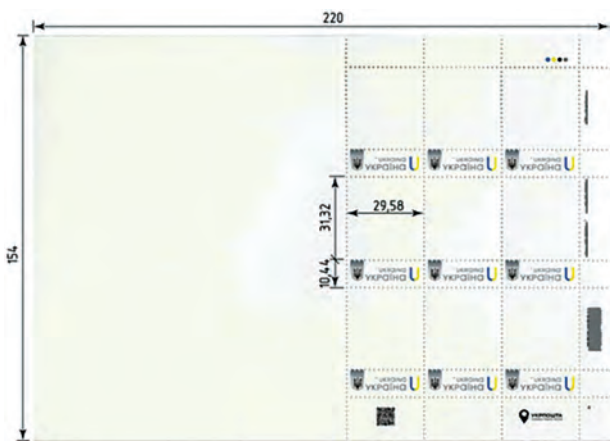

Fig. 1. Blank sheet for the manufacture of stamps in single editions

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Adobe Illustrator software, the test form contains the following test fields [11] (fig. 2):

1) control fields for reproduction of CMYK color image tone gradations;

2) text fields made with positive and negative fonts in the same color;

3) text fields made with positive and negative font in two colors;

4) areas with vertical and horizontal strokes 1–6 p thick, partially crossing areas with printed and unprinted backgrounds;

5) dashed test objects in the form of parallel straight segments of a given stroke thickness and spaces (0.12; 0.24; 0.36; 0.48; 0.6 p);

6) three mixed fields, in which the embedded color is identical to the offset imprints;

7) four areas with strokes 1 p thick, which come from one point;

8) six photos with various gradation and color content.

Equipment of various printing technologies was chosen for printing imprints: Xerox Versant 180 Press (laser), Konica Minolta bizhub c224e (laser), Epson Artisan 1430 (jet, dye-based ink), Mimaki UJ-3042 FX (UV jet). Printed with an actual resolution of 600×600 dpi in the 'best quality' mode that each device allowed. Original components and materials were used for printing: ink or toners. Color profiles were not used to determine the influence of the characteristics of the paper samples on the reproduction of color values during printing.

Printing of samples and subsequent measurements were carried out at room temperature in the range of 18–22° C. A Levenhuk DTX 90 microscope was used to take photos of the investigated imprints. Measurements on small areas were carried out using a Sigeta Biogenic lite 40x-1000x LED Bino microscope. An X-Rite SpectroEye spectrophotometer (geometry 0/45, viewing angle 2°, light source D65) was used to analyze the color and gradation characteristics of the

Fig. 2. Test form with test items

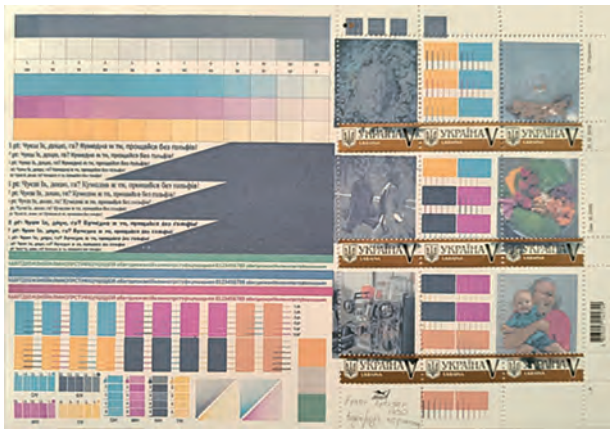

Fig. 3. Imprint on Epson Artisan 1430 printer (jet dye-based ink printing)

imprints. All measurements of color indicators were carried out taking into account the color of the paper, since it is not white, but has a yellowish tint. Using a spectrophotometer, the color indicators of the test fields in the CIE L*a*b and L*C*h color spaces, color difference (ΔE), hue difference index (ΔH) were determined.

Results

A visual analysis of imprints obtained on all types of equipment was carried out. On the sheets of gummed stamp' paper printed on the Epson Artisan 1430 printer, the ink has spread (fig. 3), the colors are desaturated, the reverse text is not reproduced. Therefore, these samples were not taken into account during further measurements and analysis.

When analyzing imprints on gummed stamp paper printed on Mimaki UJF-3042FX (fig. 4), clearly defined horizontal stripes were revealed, which are visible to the naked eye and spoil the general appearance of the imprints. The-

Fig. 4. Imprint on Mimaki UJF-3042FX digital printing machine (UV jet printing)

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refore, it can be concluded that jet printing technology is not suitable for printing on gummed stamp' paper.

Discussion

The degree of accuracy of image reproduction is assessed by two methods: visual comparison of the imprint with the original and with the help of control and measuring equipment. In practice, if the edition is not a single, the production imprints are compared with approved reference or proof imprints. If the edition consists of only several copies, then they are compared with each other for identity and the absence of critical local distortions. When evaluating a specific pictorial original, the introduction of clarifying characteristics may be provided by way of its description. However, the number of variations of pictorial originals for the creation of philatelic products is so great that it is not appropriate to describe each specific case. For the analysis of optical indicators of imprints of philatelic products made 'on demand', several indicators were selected, namely: lightness, color deviation and gradation accuracy.

In fig. 5–8 shows the effect of paper on the lightness index. The histograms are built on the basis of the measured values of the lightness index (L) on the control fields of 40 %, 80 %, 100 %. Measuring the 80 % and 40 % fields allows you to evaluate the reproduction of the gradation range of the image, as well as the accuracy of colour reproduction for different levels of image saturation. The 80 % field allows you to evaluate the accuracy of tone reproduction in the range of deep shadows closer to 100 %. The 40 % field provides information about midtones, which is important for evaluating the reproduction of images whose information content is concentrated in the halftone range.

The accuracy of the reproduction of the lightness indicator for 100 % of the test triad fields (figs. 5–8) was evaluated by comparing the measured values of the lightness indicator for 100 % of the control fields with the normative values for chalked matte paper according to the source [7]. This decision was made because the researched chalked gummed stamp' paper has approximate values of paper color

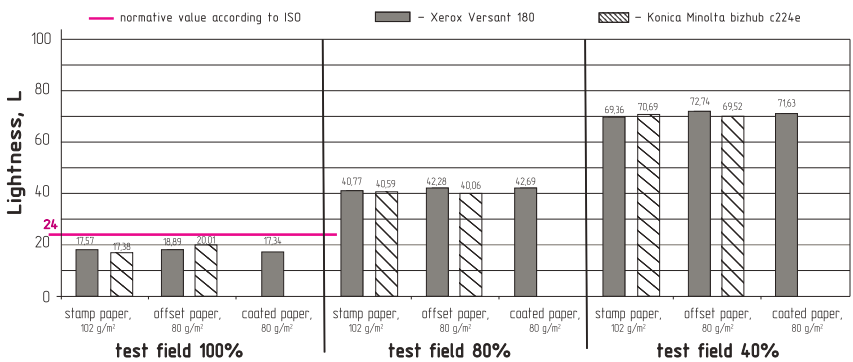

Fig. 5. The effect of paper on the lightness index of black color

according to Lab coordinates. Black color on all papers and devices was found to reproduce 4–7 units darker than the standard value, which can be explained by the thermal mechanism of fixing the toner, as opposed to the wicking and oxidative polymerization of offset inks. Also, it can be concluded that for achromatic black, the effect of paper on the lightness index is insignificant (up to 3 units), in addition,

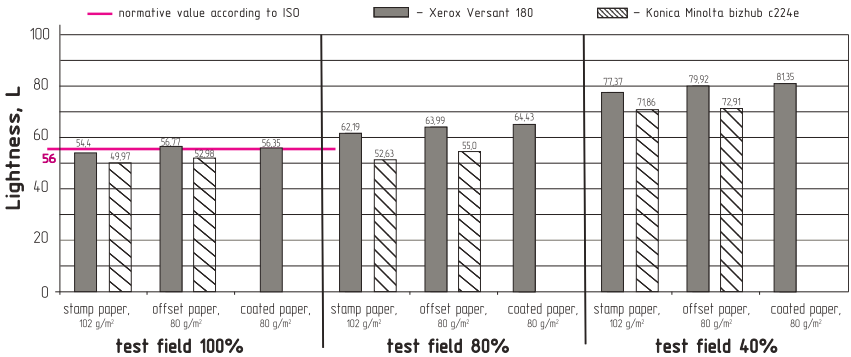

Fig. 6. The effect of paper on the lightness index of cyan color

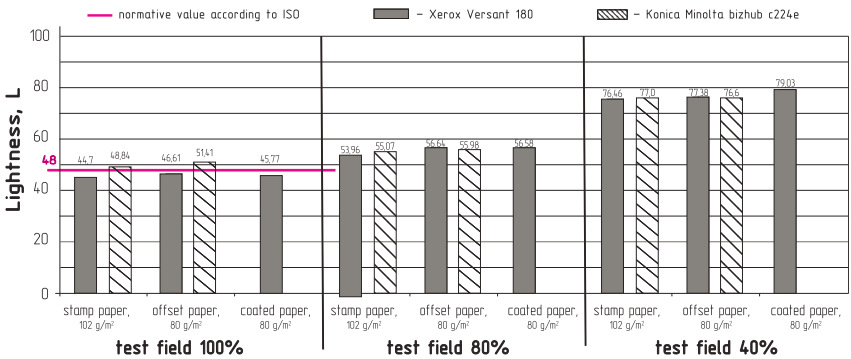

Fig. 7. The effect of paper on the lightness index of magenta color

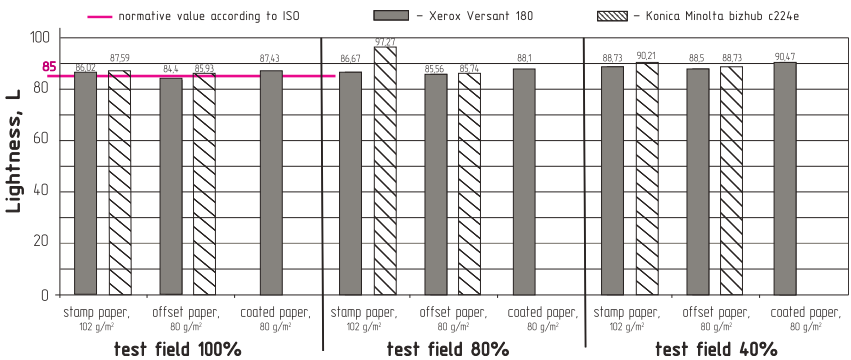

Fig. 8. The effect of paper on the lightness index of yellow color

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the measured values are practically the same for imprints obtained on Xerox Versant 180 Press and Konica Minolta bizhub c224e.

For the analysis, the obtained values of the lightness index L for chromatic test fields were compared with the normative values of lightness according to the source [8]. Based on the results of the comparison, it can be concluded that the Xerox Versant 180 Press provides a more accurate reproduction of 100 % of the CMY control fields compared to the Konica Minolta bizhub c224e. Also, based on the obtained data, it can be assumed that color reproduction on electrophotographic printing devices, to some extent, depends on the type and characteristics of the toner [8, 12]. Namely, the Xerox Versant 180 Press uses Emulsion Aggregation (EA) toner, which has smaller and more uniform particles compared to the polymerized Simitri HD Toner used in the Konica Minolta bizhub c224e. EA toner is designed specifically for professional printing in order to ensure high detail and clarity of images.

Measurements of the CMY control fields, which were obtained on branded paper on the Xerox Versant 180 Press, revealed lower lightness values compared to the Konica Minolta bizhub c224e, with the exception of Cyan, which is visually perceived to be more saturated and has a parasitic shade. The lightness index L significantly affects the visual perception of the saturation of ink' layers. For example, lighter hues may be perceived as less saturated, while darker colors appear more saturated, even though their objective saturation parameters are the same. Visually, the imprints obtained on the examined papers on the Xerox Versant 180 Press are characterized by uniform saturation of the ink layers without any color distortions, while the imprints obtained on the Konica Minolta bizhub c224e have a red parasitic shade that is visible to the naked eye.

The formula of 2000 (ΔE_{00}) was used to calculate the color difference indicator, which gives more accurate results and is recommended for use in evaluating the color indicators of printing prod-

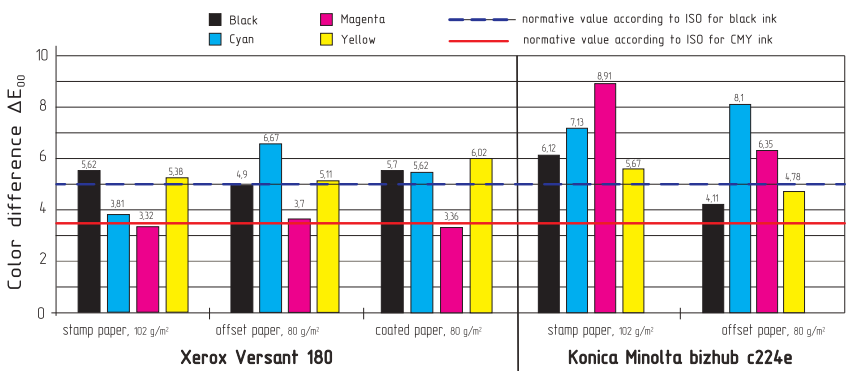

Fig. 9. Effect of paper on the color difference index for imprints (normative value according to ISO/DIS 12647-2:2013 [7])

ucts. In fig. 9 shows the effect of paper on color difference index for 100 % control fields for Xerox Versant 180 Press and Konica Minolta bizhub c224e. CD4 (standart coated matte) paper was chosen as the standard, the Lab indicators of which correspond as closely as possible to the samples of the investigated stamp paper [7].

Analyzing the obtained results, it is possible to conclude that the studied imprints on stamp' paper obtained on the Xerox Versant 180 Press are reproduced most closely to the reference values of the control fields. An excess of the ΔE_{00} indicator for black ink is observed within 0.62 units, which is associated with a lower lightness indicator compared to the standard. Analysis of chromatic control fields printed on offset and coated paper revealed a slightly higher color difference. Although visually, this difference is barely noticeable, and is manifested mainly in the lower saturation of the studied control fields (fig. 10).

On the imprints obtained on the Konica Minolta bizhub c224e, the color difference indicators are higher compared to the Xerox Versant 180 Press, which is also confirmed by visual evaluation, namely, a characteristic red tint is observed on the imprints (fig. 10, table).

In fig. 10 presents the simulation of color reproduction of the studied 100 % CMYK test fields on the studied materials and equipment, according to the measured color values in the Lab space. This method of visualizing color reproduction on different surfaces is quite convenient for visual analysis of the accuracy of color reproduction on different materials.

Based on a visual comparison of the reproduction of the control fields, relative to the digital file, it can be concluded that the black color is reproduced slightly lighter on all paper samples. CMY control fields on branded paper reproduce slightly darker and have a warm yellowish tint, which is inherent to the paper. To achieve a higher accuracy of reproduction of images on stamp paper, it is recommended to use output profiles that will contribute to reducing the intensity of the 'yellowish' tint of the paper.

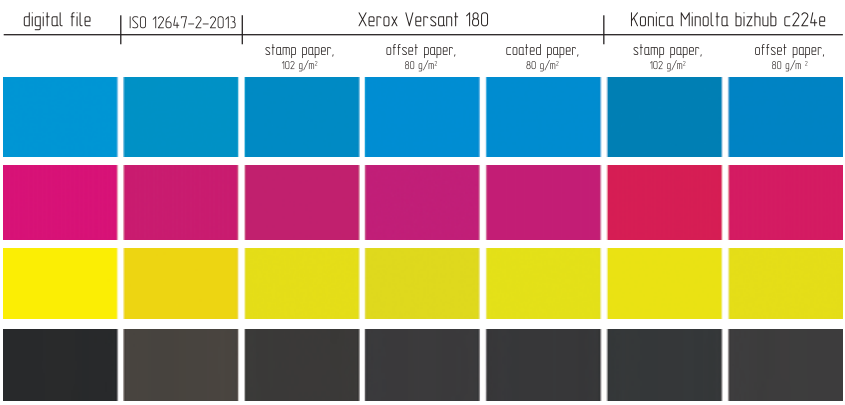

Fig. 10. Modeling of reproduction of the studied control fields

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To determine the effect of paper on the accuracy of color reproduction, the color tone indicator was also evaluated. For triad offset inks, permissible deviations in color tone should not exceed 3 [7]. According to the calculations, the deviation of the color tone for black corresponds to the norm for offset printing, which indicates that the influence of the paper is negligible. For CMY chromatic control fields, the color difference indicator is much higher than normal, although the color difference indicator for the investigated fields is not so critical. On the Xerox Versant 180 Press, the 100 % Cyan control field is reproduced with greater distortion on offset and coated papers, which is confirmed by the data in fig. 9, 11 and can be clearly seen in fig. 10. CMY control fields reproduced on a Konica Minolta bizhub c224e are characterized by the presence of a 'parasitic' shade, which

Results of control field measurements in the CIE Lab color space

			Black	Cyan	Magenta	Yellow
Xerox Versant 180	stamp paper, 102 g/m^2	L	17.57	54.40	44.70	86.02
		a	-0.18	-24.79	68.82	-11.98
		b	-1.05	-42.00	-3.14	91.72
	offset paper, 80 g/m^2	L	18.89	56.77	46.61	84.40
		a	-0.35	-18.91	66.39	-11.37
		b	-0.81	-45.42	-9.14	83.82
	coated paper, 80 g/m^2	L	17.34	56.35	45.77	87.43
		a	-0.23	-21.27	70.28	-12.96
		b	-0.92	-45.95	-7.15	92.56
Konica Minolta bizhub c224e	stamp paper, 102 g/m^2	L	17.38	49.97	48.84	87.59
		a	-0.74	-23.47	68.64	-11.08
		b	-1.30	-41.31	19.09	100.34
	offset paper, 80 g/m^2	L	20.01	52.98	51.41	85.93
		a	-0.26	-16.69	62.68	-10.75
		b	-0.49	-44.04	10.32	91.10
ISO/DIS 12647-2:2013 (CD 4 Standart coated matte)		L	24	56	48	85
		a	1	-33	68	-2
		b	2	-42	-1	83
Digital file		L	11	57	50	94
		a	0	-40	80	-5
		b	1	-52	-2	102

can be observed in fig. 10, Magenta control fields are rendered almost red.

Based on the results of the research, it can be concluded that the researched gummed stamp' paper is quite suitable for the fulfillment of individual personalized orders. To print stamp paper, it is recommended to use laser technology of electrophotographic digital printing, in particular, choose professional printing equipment that has advanced color management with tools. Such as the Automated Color Quality Suite (ACQS), which allows for high accuracy of color reproduction, implemented in the examined Xerox Versant 180 Press device. It was established that jet printing technology is not suitable for printing stamp paper.

Conclusions

Based on the results of a visual evaluation of test imprints obtained on all types of equipment selected for the study, it was established that jet printing technology and UV printing are not suitable for forming images on gummed stamp' paper.

Summarizing the results of the study of the color characteristics of the imprints, namely: lightness index, color difference and color tone, it can be concluded that all the studied imprints have flaws in one or another area. Black color is reproduced slightly lighter on all paper samples. On the imprints obtained on the Konica Minolta bizhub c224e, the color difference indicators are higher compared to the Xerox Versant 180 Press.

The researched imprints on stamp paper obtained on the Xerox Versant 180 Press are reproduced most closely to the reference values of the control fields.

Based on the results of the research, it can be concluded that the researched gummed stamp' paper is quite suitable for the execution of individual orders by the electrographic printing method.

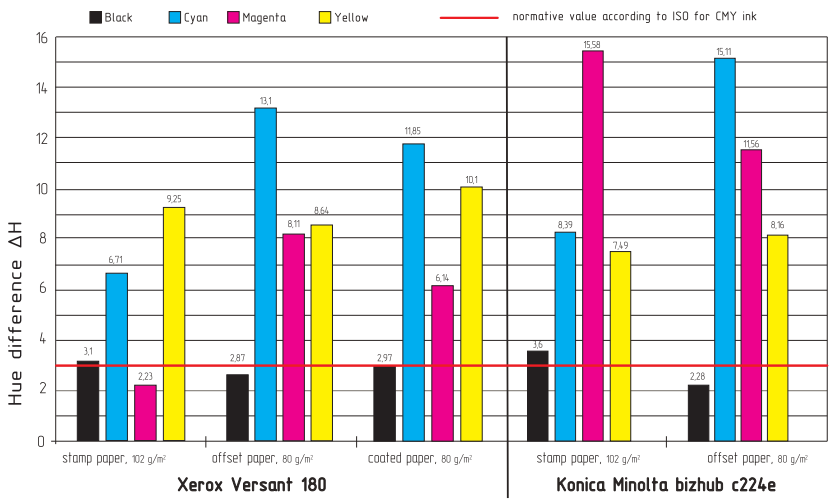

Fig. 11. The influence of the printed material on the hue difference index ΔH (normative value according to ISO/DIS 12647-2:2013 [7])

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В статті представлено результати досліджень оптичних показників відбитків цифрового друку на маркованому папері. За результатами візуальної оцінки пробних відбитків, отриманих на всіх типах обладнання, обраних для дослідження, встановлено, що струминна технологія друку та УФ-друк не підходить для формування зображень на гумованому папері. За результатами проведених досліджень, можна зробити висновок, що досліджуваний гумований марковий папір цілком придатний для виконання одиничних персоніфікованих замовлень електрографічним способом друку.

Ключові слова: цифровий спосіб друку; маркований папір; оцінка якості; оптичні показники відбитків; дефекти цифрового друку.

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