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Testing the Printing Systems for Enlarging Color Reproduction

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Abstract. The process of manufacturing multicolor printed matter is rather complicated as the components of printing system are diverse by the configuration and have a complex of various properties that in aggregate form production quality. Difficulties in solving the problem of ensuring the quality of a multicolor image are determined with the instability of the properties of printing system components, their diversity, both in physicochemical and structural-mechanical properties. All this causes different divergence of the process parameters and does not allow obtaining a qualitatively stable ready-made product. The results of investigation of the possibilities in enlarging color reproduction of a printing system the "inkjet printer – paper" are presented in the work. The role of paper sheet characteristics is noted. It is shown that the priority belongs to paper with a uniform, microporous surface.

1. Introduction
Now in graphic arts the percentage of inkjet printing is increasing due to the operability of obtaining production prints of pictures and the permanently updated assortment of printing systems components. The requirements to improve the quality and competitiveness of Russian multicolor printed matter are increasingly growing due to the constantly rising requirements from the consumers.

The main index of printed matter quality is the color of the print, as a result of interactions between the printing properties of a paper carrier and inks during their spreading and fixing in complex, in a printing press. In current classification of types of printed paper a paper for a contactless printing, i. e. copier, inkjet, electrographic, etc. is marked out in a separate group. To the paper for digital printing, there are requirements that are different from those demanded for printed materials for classical printing methods. The paper for copier must be sufficiently uniform and smooth. The toner fixing in this case will depend on the optimum balance between the surface topography and the thermal properties of the printing material. In inkjet paper a balance between surface topography, porous structure, chemical composition and mechanical strength should be kept. The requirement for such paper are: it must hold color pigments close to the surface, limit and control the spread of the ink, control the amount and speed of its absorption, sustain the ink vehicle until its complete evaporation, form a uniform printed surface. At present, the correlations between the printing and surface properties of paper are not exactly investigated. They could let the forecasting of the printing quality for existing materials for digital printing and are of great practical interest.

2. Statement of the problem
The problem of color reproduction today is successfully solving with the help of color management systems, in particular, CMS. Nevertheless, due to a number of limitations of printing synthesis, the

color of the original can be reproduced on the print only identically subjectively, and specified first of all because of the limited range of printing synthesis. Thus it is always actual, to expand the color gamut of the printing system which is achieved in inkjet printing by seeking for optimal printing settings, improving the properties of inks, matching a paper carrier and modifying its surface.

For the optimal choice of printed system components during reproduction of the originals with different complexity groups by the inkjet printing various approaches are known. Improving the quality of inkjet printing, according to [1], can be achieved by modifying the paper surface with surfactants and a cationic polymer. As a result, this treatment has a slight effect on its structural and surface properties, but nevertheless improves the quality of inkjet printing (an increase in gamma area is up to 12 per cent in estimation of color properties). The results of the printing were interpreted by the authors, taking into account the nature of inks and pigments and the molecular structure of the inks, estimated using the IR spectroscopy method. However, despite the positive results achieved, in practice, this type of processing should be carried out directly in the process of paper production.

The key point in the work [2] is the investigation of the fixation of ink colorants in the surface and volume coating layers. The authors of [2] specify that the most important properties of surface coating are the characteristics of the porous structure – the pore size, the amount and the net created by them - and the chemical nature. It, by the authors' opinion, are responsible for ensuring correct fixation of the colorant on paper and quality indexes: high optical density, sharpness, abrasion resistance, etc. In this field of research papers [3–11] are of interest but with the difference that they consider the other methods of printing, mainly offset printing.

A similar opinion is held by the authors of [12]. They believe that coating of the inkjet paper surface should be planned in such a way as to provide good printability with the use of the structural parameters, the pore grid, the chemical composition of the coating, and the properties of the polymer additives. The main direction in this work is to find out how the ions charge and in particular its distribution in the coating layer combines with the binder to influence on the properties of colorant fixing. The aim of the work is to reveal the possibility of enlarging the color reproduction in the printing system "inkjet printer – paper".

3. Materials and Methods

The objects of research are the components of printing systems: samples of paper for digital printing of leading manufacturers in accordance with the assortment of the Russian market, and inkjet systems: Riso (printing system No. 1) and Epson (printing system No. 2).

The measurement of the color coordinates was carried out using a SpectroEye spectrophotometer from Gretag Macbeth. The results were compared using the Adobe PhotoShop CS software. The test chart contains CMYK-colors and their binary overlays (RGB): cyan, magenta, yellow, black and thus red, green, blue. Fillings of the chart fields was made with help of software and contain the dots of 100, 80 and 40% (Figure 1).

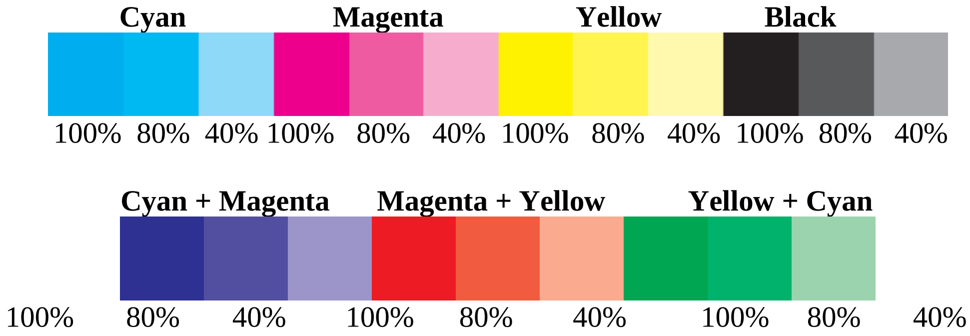

Figure 1. A Test Chart

To determine the surface characteristics of the paper samples tested, a non-contact profilometry method was used using the Micro Measure 3D station [13]. In order to exclude defective samples, their geometric uniformity was preliminarily estimated, the necessary procedures for acclimating the paper were carried out.

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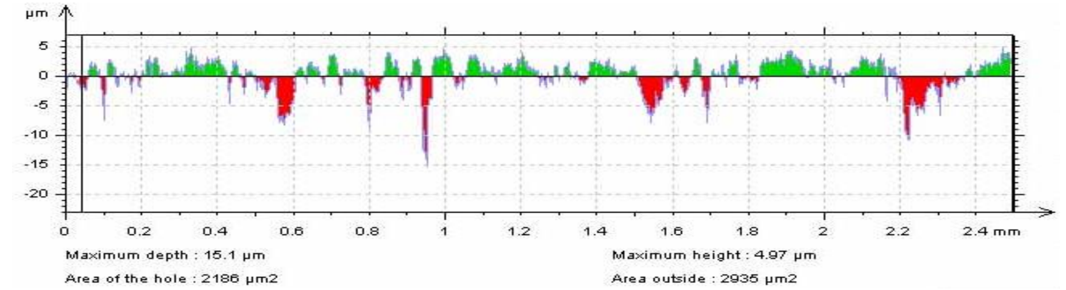
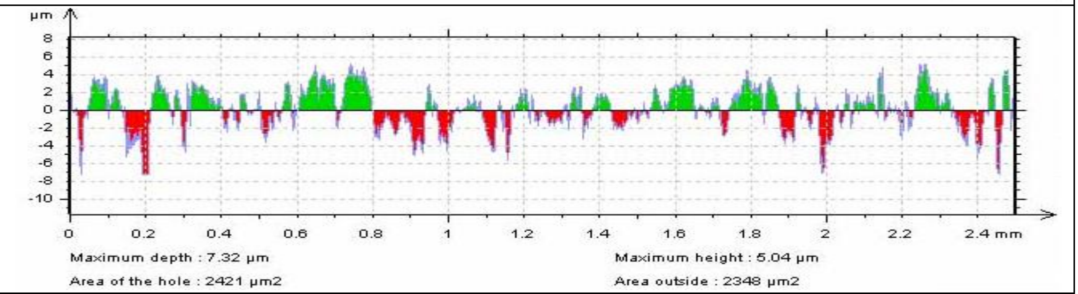
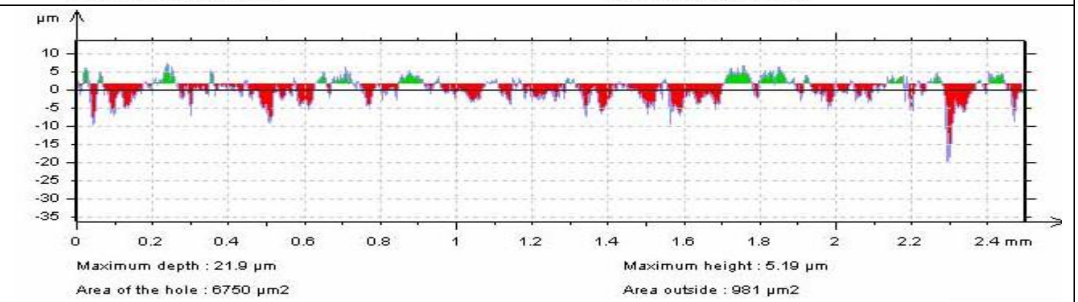
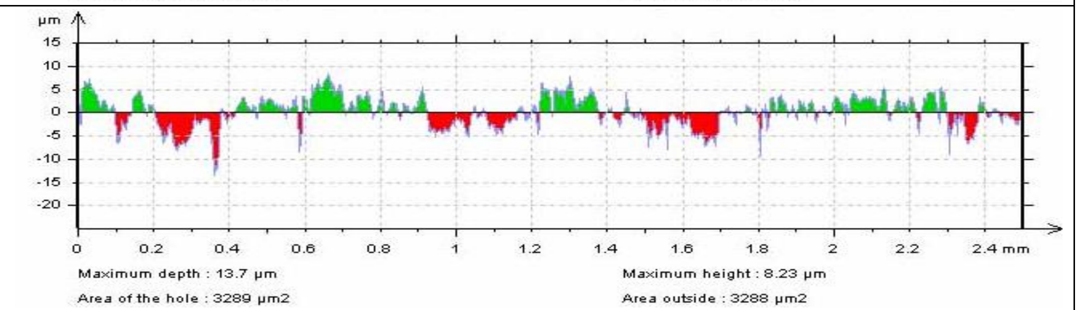
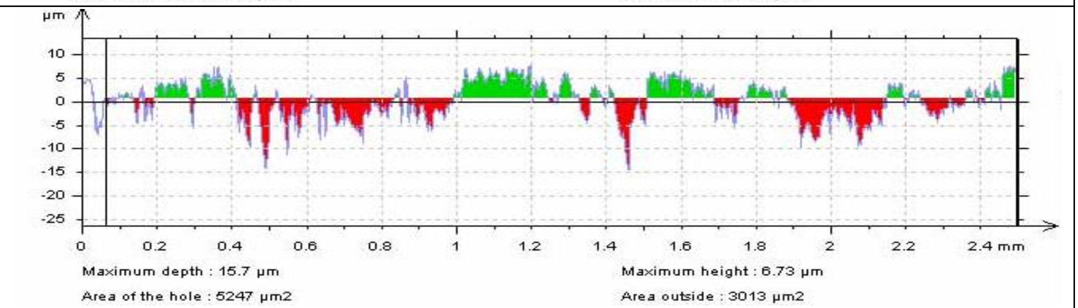
4. Experimental Results

The results of the experiments are presented in Tables 1–5. Table 1 shows the scanned area of the surface profile of the tested paper samples in X and Z coordinates with the calculation of the area of peaks S_{peak} and valleys S_{valley}.

Table 1. Surface Profile of Testing Paper Samples

Number of paper sample	Profile by X and Z with the calculation of peaks S_{peak} and valleys $S_{вп}$ of a surface
1	
2	
3	
4	
5	

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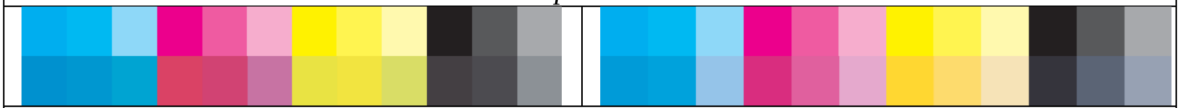
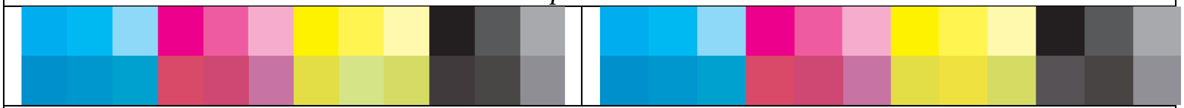
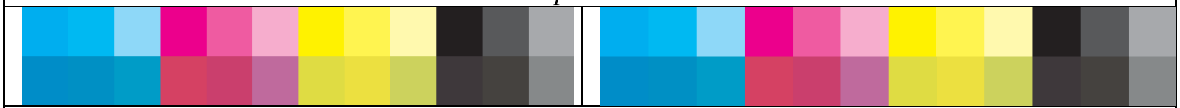
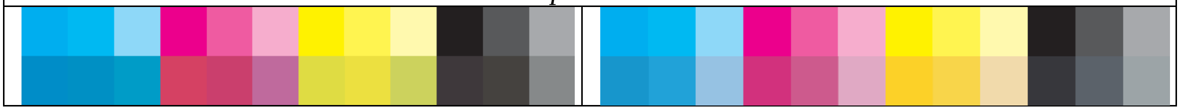
Tables 2–4 show the results of experiments of printing systems.

Table 2. A Test Chart (upper line) and its print (lower layer) by different printing systems

Printing System No.1				Printing System No.2			
C	M	Y	K	C	M	Y	K
Paper No. 1							
							
Paper No.2							
							
Paper No. 3							
							
Paper No.4							
							
Paper No. 5							
							

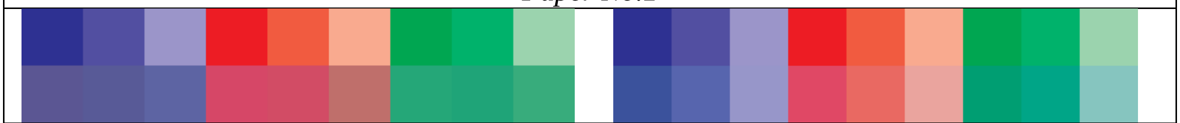
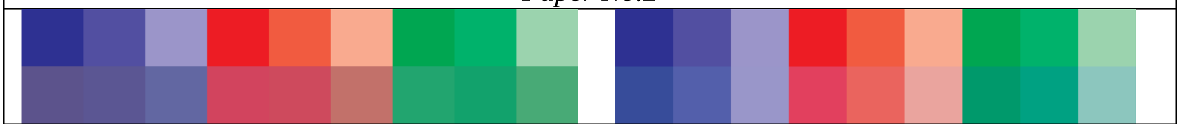
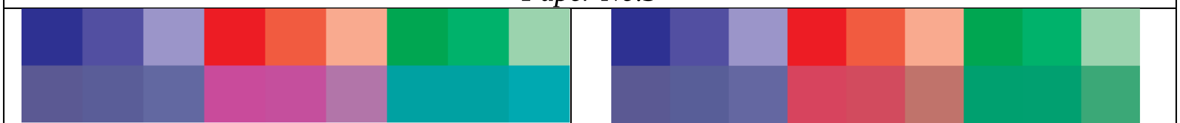
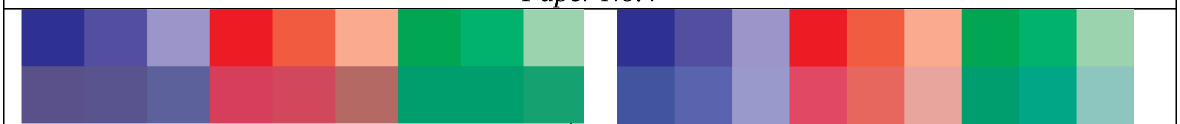
Printing System No.1			Printing System No.2		
B	R	G	B	R	G
Paper No.1					
					
Paper No.2					
					
Paper No.3					
					
Paper No.4					
					
Paper No.5					
					

Table 2 shows the results of printing a test chart by various printing systems: solid colors are the color fields with 100 % fill; continuous-tone elements – the color fields with a print, representing a certain percentage of the solid fill of 80 % and 40 % and are used for measuring the contrast of printing and tone change; binary overlays (RGB fields) – printing one color over another – cyan /magenta, magenta/ yellow and cyan / yellow. Table 3 and 4 show the results of measurements of the optical densities for the obtained printouts sample of the test chart in front.

Table 3. Optical densities of the fields of basic colors obtained by the printing of test chart with different printing systems

Number of paper sample	Field	Printing System No.1				Printing System No.2			
		C	M	Y	K	C	M	Y	K
1	100 %	0.81	0.83	0.84	0.95	0.71	0.99	1.00	1.00
	80 %	0.80	0.82	0.83	0.91	0.69	0.71	0.79	0.71
	40 %	0.72	0.58	0.73	0.46	0.35	0.34	0.34	0.36
2	100 %	0.85	0.86	0.88	0.98	0.76	1.00	1.00	1.00
	80 %	0.84	0.86	0.87	0.90	0.73	0.75	0.75	0.78
	40 %	0.79	0.58	0.73	0.44	0.35	0.34	0.32	0.36
3	100 %	0.82	0.82	0.85	1.00	0.71	1.00	0.98	1.00
	80 %	0.82	0.83	0.86	0.93	0.66	0.71	0.73	0.72
	40 %	0.70	0.56	0.73	0.44	0.33	0.32	0.32	0.35
4	100 %	0.78	0.83	0.83	0.91	0.69	1.00	1.00	1.00
	80 %	0.78	0.82	0.82	0.83	0.65	0.76	0.77	0.71
	40 %	0.67	0.58	0.71	0.44	0.33	0.33	0.34	0.33
5	100 %	0.83	0.84	0.85	0.98	0.69	0.96	0.99	1.00
	80 %	0.83	0.87	0.85	0.92	0.66	0.68	0.76	0.71
	40 %	0.72	0.61	0.74	0.47	0.32	0.30	0.34	0.33

Table 4. Optical densities of the fields of binary overlays of basic colors obtained by the printing of test chart with different printing systems

Number of paper sample	Field	Printing System No.1			Printing System No.2		
		R	G	B	R	G	B
1	100 %	0.86	0.73	0.77	0.89	0.87	0.94
	80 %	0.83	0.73	0.76	0.88	0.77	0.77
	40 %	0.76	0.70	0.71	0.45	0.37	0.41
2	100 %	0.89	0.80	0.83	0.94	0.91	1.00
	80 %	0.85	0.80	0.81	0.91	0.86	0.82
	40 %	0.76	0.72	0.71	0.45	0.37	0.42
3	100 %	0.85	0.76	0.79	0.88	0.87	0.91
	80 %	0.82	0.76	0.78	0.89	0.77	0.75
	40 %	0.74	0.70	0.70	0.46	0.35	0.40
4	100 %	0.84	0.77	0.79	0.89	0.88	0.91
	80 %	0.82	0.76	0.76	0.88	0.78	0.75
	40 %	0.74	0.69	0.68	0.47	0.35	0.39
5	100 %	0.86	0.77	0.89	0.89	0.90	0.92
	80 %	0.82	0.77	0.78	0.87	0.77	0.76
	40 %	0.76	0.72	0.73	0.50	0.38	0.39

Fig. 2, 3 presents the hexagons of color gamut for printing systems No. 1 and No. 2, constructed from the results of measuring the color coordinates of 100% solid pure colors (C, M, Y, R, G, B) in color system L *a* b –1976.

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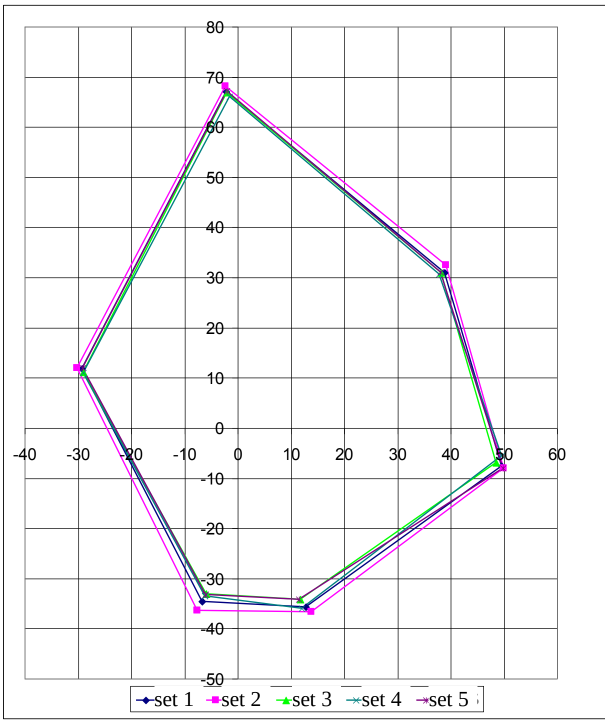

Figure 2. Hexagrams of color gamut of printing system No. 1 on the chromaticity diagram a*b* (the abscissa axis is a^{*M}, the ordinate axis is b*; sets 1–5 of paper No. 1–5, respectively)

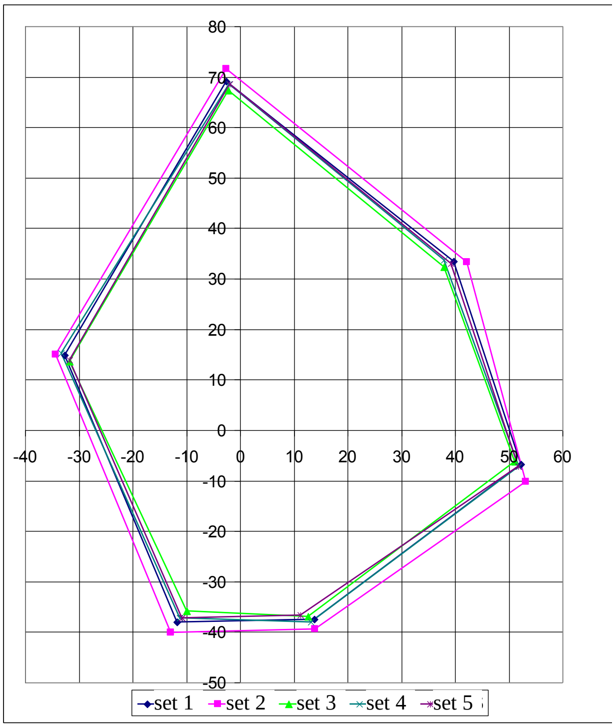

Figure 3. Hexagrams of color gamut of printing system No. 2 on the chromaticity diagram a*b* (the abscissa axis is a^{*M}, the ordinate axis is b*; sets 1–5 of paper No. 1–5, respectively)

5. Results and Discussion

Estimation of the print printed on paper No. 1 by the printing system No. 1 showed that 100 % and 80 % fields practically not differ, and a 40 % field has an optical density much subjects to the digital original. On the contrary, the print obtained with the printing system No. 2 has better characteristics in compare with the printing system No. 1. The colors are much more saturated and closer to the digital original, and the color gamut (Figures 1, 2) is much larger. It is noted that 100 % and 80% fields are sufficiently recognizable, and a 40 % field has an optical density close to the original. At the same time, the yellow color on the paper differs from the digital original. The reproduction of the color with minimal deviation is seen on the the printing system No. 1 with the improved technology of forming ideally round points and drops of variable size for solids and small details of the image.

Prints on paper No. 2, obtained in the same conditions as compared to prints on other test paper samples, have a color rendition that is more identical to the original, and the color gamut on this paper is larger than on the others (Figures 1, 2). This paper sample is characterized by the most uniform closed surface (depth of the depressions is 7.32 μm, height of peaks is 5.04 μm) with an average pore depth of 1.25 μm (Table 1, position 2)

Testing of the prints obtained on paper No. 3 showed that the red and green fields are very brighten, a tinge of magenta hues is noticeable, which is clearly visible on the green field (Table 2, position 3).

On the test chart of the paper sample No. 4 with an average pore depth of 1.96 μm, deviations of fills for 100 and 80 % fields are observed, especially in reproduction of yellow; because of the strong darkening of colors, the 40 % field has a fill close to 80 % (Table 2, position 4).

For the prints on sample paper No. 5, all three fields are practically a single-color solid, this is clearly visible on binary colors, probably due to the lower whiteness of the paper and the less uniform surface of the paper: the depth of the valleys is 15.7 μm, the height of the peaks is 6.73 μm (Table 1, position 5).

6. Conclusion

Analysis of the experimental data made it possible to evaluate the correlation between the quality index of color reproduction and the characteristics of paper surface. The presence of a macroporous structure significantly reduces the quality of reproduction of a multicolour original. The obtained results show that the studied systems reproduce different amounts of colors. The percentage of reproduction of color coordinates for the main colors relatively to the test samples varies from 70 to 98 % that conform to ISO 12647-1-2 **-** the standard of offset printing (the variability of pure colors should be at least 68 %).

The use of testing techniques for printing system components will provide the correct choice of the printing system, the stability of printing process and forecast the expected quality by achieving the necessary conditions for proper color reproduction.

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