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IMPACT OF DAMPENING SOLUTION CHARACTERISTICS ON THE QUALITY OF OFFSET PRINTING IN THE MANUFACTURING OF SECURITY PRODUCTS

A new formula of a dampening solution for the offset printing method has been developed, which, compared to the standard solution, stabilizes its hardness. The influence of the test dampening solution on the quality of offset printing and the rate of ink layer fixation was studied. The research results demonstrated that modifying the damping solution formula, while maintaining consistently high graphic precision and color fidelity of imprints, reduced ink setoff, as confirmed by drying test results. This improvement will help reduce waste during the technological stage of offset printing for security printing products.

Keywords: wet offset printing; dampening solution; ink imprint, set off; optical density; color differences; security products.

Introduction

The requirements for the protection of valuable papers and documents of strict accounting and reporting (VPDSAR) — such as banknotes, various forms, and passport products — are exceptionally high. Consequently, the manufacturing technologies for such products are continuously evolving, with the implementation of innovative solutions aimed at enhancing security. One key component of the security product manufacturing system is printing on specialized restricted-access equipment, which can only be utilized by enterprises authorized to produce VPDSAR [1].

The technological process of banknote production employs several consecutive printing methods, including offset printing (dry offset: Orlof, iris; wet offset), intaglio (engraved printing), screen printing, and letterpress (for numbering). Previous studies [2] have identified that the majority of defects in banknote products are associated with suboptimal quality in intaglio (21.1 %) and offset (17.4 %) printing processes.

The initial technological stage involves printing on the Super Orlof Simultan IV printing press, designed for simultaneous double-sided printing of banknotes using the offset printing method (both wet and dry) with the application of classical, Orlof, and iris printing techniques. Key challenges in the printing process include ink greasing during wet offset printing, extended stabilization of inks in the wet offset sections after technical cleansing, and prolonged drying of ink imprints. One of the potential causes of these issues is the unsuitable composition of the dampening solution, as noted in previous works [3–6].

To address these challenges, the following actions were undertaken:

— analysis of the composition and technical parameters of the operational dampening solution,

— adjustments to the composition of the solution and preparation of a test batch of the experimental dampening solution,

— trial printing using the test dampening solution,

— analysis of print quality produced using both the operational and test dampening solutions,

— evaluation of the ink drying rate on imprints produced with the operational and test dampening solutions.

The aim of this study is to investigate the impact of the test dampening solution on printing quality and the fixation of the ink layer on imprints, as significant ink pickling presents an obstacle to performing subsequent technological operations in the production process.

Methods

The hardness of the dampening solution affects the emulsification of the ink during the printing process [4]. When the balance of ink and water is unstable, the ink spreads, which can lead to increased droplet formation and the appearance of shadowing on ink imprints. This effect can be reduced by stabilizing the water hardness [3]: droplet formation is reduced and controlled. Thus, to achieve optimal print quality, it was decided to stabilize the hardness of the dampening solution.

The composition of the operational dampening solution, consisting of demineralized water, BottcherPro S-3020 dampening solution additive and isopropyl alcohol, was analyzed. After measurements, it was determined that the demineralized water used to prepare the solution was too soft, and the additive added to the dampening solution did not increase the hardness of the solution to the required level.

To determine the potential for improving printing quality through adjustments to the composition of the dampening solution, a research algorithm was developed:

1. The effect of the concentration of BottcherPro Calcit, a solution for stabilizing water hardness, on the physicochemical properties of the dampening solution was studied.

2. Test printing was conducted, followed by the determination of the optical characteristics of the imprints.

3. Potential scalding was investigated using intaglio printing, where printed sheets were alternated with blank sheets in the printing nip, and the operational control scales were subsequently analyzed.

The study utilized BottcherPro Calcit, a water hardness stabilizing solution manufactured by Felix Böttcher GmbH & Co. KG (Germany)

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[7]. The composition of the test dampening solutions, as well as their measured hardness and pH values, are presented in Table 1.

The hardness measurements were performed using ‘Vodomer-Hardness’ indicator strips manufactured by ‘Norma’ LLC [Test strips Norma Vodomer-Hardness №10 for determining water hardness [8]]. The pH values were measured using a portable pH meter, Mettler Toledo [9].

Table 1 indicates that the investigated solution for stabilizing hardness, BottcherPro Calcit, does not significantly affect the pH level of the dampening solution, regardless of its concentration.

Based on the obtained results, it can be concluded that the BottcherPro Calcit solution stabilizes the hardness of the solution at 8 dH with a 0.5 % concentration, which aligns with the recommendations provided by the manufacturer of BottcherPro Calcit. The manufacturer of the wetting solution recirculation system, Technotrans, recommends maintaining the solution hardness within the range of 7–10 dH, as specified in the technical documentation [10].

The printing of test samples was conducted on the Super Orlof Simultan IV printing machine, using both the standard and test dampening solution No. 1, which were poured into two Technotrans Alpha D reservoirs.

A visual analysis of the obtained ink imprints was conducted. It was found that reducing the level of dampening solution did not lead to the appearance of shadowing on the sheets, indicating that a lower level of dampening could be maintained during printing. No excessively light (unprinted) areas were observed on the printed image on the sheets after the technical cleansing of the printing machine.

Results

For an objective comparison, densitometric and spectrophotometric measurements were performed on the operational control scales of the imprints, obtained using the standard and test dampening solutions. The measurements were conducted using the TECHKON DENS densitometer and the Datacolor 550 spectropho-

Table 1

Composition of test samples of the dampening solution

Sample №	Composition of dampening solution				Hardness, mmol/dm^3	Hardness, dH	pH Indicator
	Demineralized Water	Bottcher Pro S-3020	Isopropyl Alcohol	Bottcher Pro Calcit			
Standard dampening solution	87 %	3 %	10 %	—	0,75	4	5,13
Test sample № 1	86,5 %	3 %	10 %	0,5 %	1,5	8	5,14
Test sample № 2	86 %	3 %	10 %	1 %	3	16	5,15

tometer on the operational control scales for two ink colors. Measurements were taken at three areas for each color, followed by the calculation of the average value. The measurement results were used to determine the change in optical density, specifically the difference between the optical density values for the two imprints (ΔD) and the color differences (ΔE) (Table 2) [11].

Based on the obtained data, it can be concluded that the change in the dampening solution does not have a significant impact on the optical density and color characteristics of the imprints.

The sheets printed with the dampening solution (test sample № 1) and the same number of sheets printed the same day with the standard dampening solution formula were transferred for technological drying in a chamber where the air temperature is maintained at 20–22° C and relative humidity at 53–55 %, regulated by industrial air conditioners.

To investigate the ink scalding, a drying test on semi-finished products was conducted on the Super Orlof Intaglio III machine on the 7th day after printing. Six sheets of each type were interleaved with clean sheets and passed through the printing machine to monitor changes in image saturation.

It was found that when passing through the intaglio printing machine, which applies extremely high pressure in the printing nip, the ink from areas of the image that had not fully dried was transferred from the printing cylinder to the clean paper as it passed through.

The results of the drying test showed that the sheets printed with the test dampening solution #1 on the 7th day after offset printing displayed less ink setoff on the paper that had been interleaved with the printed sheets (see Figure 1).

Since the ink setoff occurred in the form of spots, and the color on the control scales was uneven, it was decided to determine the color differences of the images by the deviation of the average color [12]. This method involves transforming the image into one conditional pixel, which is a mixture of the colors of all its pixels (Fig. 2). The digital image in the RGB color space can be represented as an

Table 2

Optical density values and color differences of imprints

	Optical Density		ΔD	Colour coordinates CIE 1976 (L*, a*, b*)						ΔE
				L	a	b	L	a	b	
	Standard dampening solution	Test dampening solution №1		Standard dampening solution			Test dampening solution № 1			
Colour 1	0,38	0,37	0,01	68,07	16,4	4,93	69,05	15,39	4,69	1,43
Colour 2	0,37	0,35	0,02	68,26	-2,6	-14,14	70,00	-2,61	-12,86	2,16

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aggregate of color channel matrices: red $R = (r_i, r_j)_{m\times n}$, green $G = (g_i, g_j)_{m\times n}$ and blue $B = (b_i, b_j)_{m\times n}$.

The coordinates of the average colour of the image are found as normalized sums of all matrix elements reduced to the number of pixels by the size of the colour channels of all pixels of the image

$$R = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n} r_{ij},$$

$$G = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n} g_{ij},$$

$$B = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n} b_{ij}, \qquad (1.1)$$

To define ΔF_k — the deviation from the standard of the average colour of the evaluated image is estimated as the distance between the ideal vector $f_0 = \{R_0, G_0, B_0\}$ of the average colour of the reference image, where R_0, G_0, B_0 are the colour coordinates for each RGB channel of the reference image, and the vector of the evaluated image $f_k = \{R_k, G_k, B_k\}$, where R_k, G_k, B_k are the colour coordinates for each RGB channel of the evaluated image, based on various metrics, in particular, the Euclidean metric [13]:

$$\Delta F_k = \sqrt{\left(R_0 - R_k\right)^2 + \left(G_0 - G_k\right)^2 + \left(B_0 - B_k\right)^2}, \qquad (1.2)$$

where R_0, G_0, B_0, R_k, G_k, B_k are defined by equation (1.1).

The data obtained for the imprints before and after the drying test are shown in Table 3, and the average colour between

— the imprint before the drying test and the imprint obtained with the standard dampening solution after the drying test ($\Delta F(1;2)$);

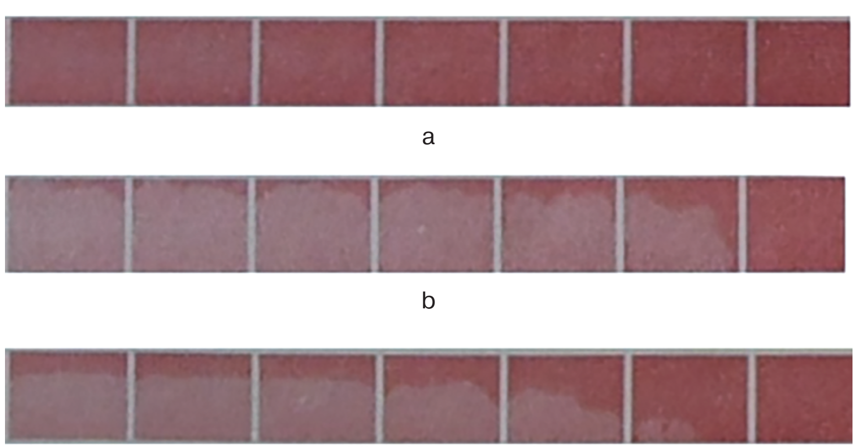

Figure 1. Photographs of the control scales; ink #1; a — imprint before the drying test; b — imprint obtained with the standard dampening solution after the drying test; c — imprint obtained with the test dampening solution after the drying test

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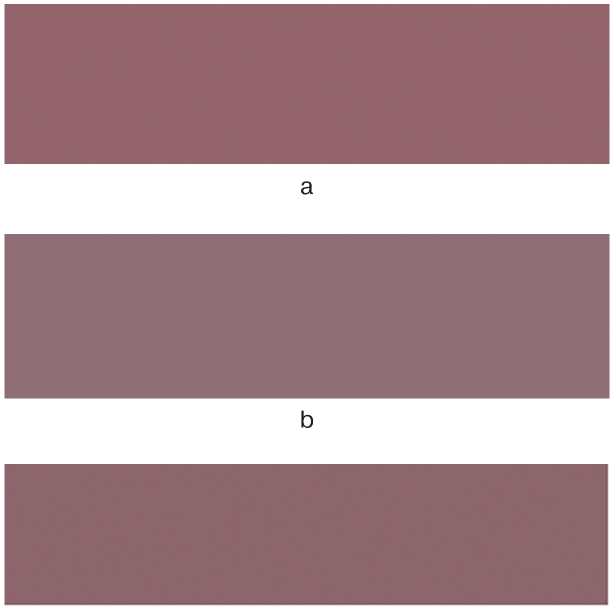

Figure 2. Results of average color formation for ink № 1: a — imprint before drying test; b — imprint obtained with standard dampening solution after drying test; c — imprint obtained with test dampening solution after drying test

— the imprint before the drying test and the imprint obtained with the test dampening solution after the drying test (ΔF(1;3)).

Discussion

The deviation of the average colour of the image of the imprint before the drying test and the imprint obtained with a standard dampening solution after the drying test is 22.02 for ink No. 1 and 11.09 for ink No. 2. The deviation of the average colour of the image of the imprint before the drying test and the imprint obtained with

Table 3

Colour coordinates of the average colour of imprints

Image	Ink № 1			Ink № 2		
	R	G	B	R	G	B
The imprint before the drying test (№ 1)	155	108	109	112	124	154
The imprint made with a standard dampening solution after the drying test (№ 2)	157	123	125	118	131	159
The imprint made with the test dampening solution after the drying test (№ 3)	149	111	111	111	123	149
$\Delta F_{1;2}$	22,02			11,09		
$\Delta F_{1;3}$	7,0			5,2		

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the test dampening solution after the drying test is 7.0 for ink No. 1 and 5.2 for ink No. 2. Based on the results of the data obtained, it can be concluded that the use of the test dampening solution contributes to better drying of the ink layer and prevents the ink layer from peeling and tearing off at the stage of further technological operations.

Conclusions

The composition and technical parameters of the operational dampening solution for offset printing were analyzed and it was determined that demineralised water for the preparation of the solution is too soft and the additive added to the dampening solution does not raise the solution's hardness to the required level.

A formula of a test dampening solution for offset printing was developed, which, compared to the standard solution, allows stabilizing its hardness.

A test printing was carried out and the effect of the test dampening solution on the quality of offset printing and the speed of ink layer fixation was investigated, which allowed us to determine that changing the formula of the dampening solution does not affect the quality of printing, but the results of the drying test showed that the sheets printed with the test dampening solution have less fading.

The rate of ink fixation on the imprints obtained using the operational and test dampening solution was analyzed and it was determined that the sheets printed with the test dampening solution on the 7th day after printing showed less setoff on the paper used to transfer the printed sheets.

The colour differences of the images obtained for the imprints before and after the drying test were compared by the deviation of the average colour of the image. It was found that the use of the test dampening solution contributes to better drying of the ink layer and prevents the ink layer from fading and tearing off at the stage of further technological operations.

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Keywords: offset printing with dampening; dampening solution; ink imprint; fading; optical density; color differences; protected products.

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