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TECHNOLOGICAL FEATURES OF COLOR REPRODUCTION OF IMPRINTS USING DIGITAL PRINTING

The color characteristics of electrophotographic and ink jet printing in the CIE Lab system were analyzed. The influence of the characteristics of different types of surface of the printed material on the accuracy of color reproduction was established.

Keywords: color reproduction accuracy; electrophotographic printing; ink jet printing; color coverage; color differences.

Introduction

Trends in the production of promotional products are aimed at reducing print runs and increasing the variety of printing. Due to the capabilities of promotional products (billboards, posters, calendars, business cards, invitations, postcards, diplomas, certificates, envelopes, letterheads, labels, stickers, booklets, brochures, notebooks, etc.), which are produced in small runs and in a short time, digital printing for such products are relevant and optimal in terms of cost.

Among the existing varieties of digital printing: ink jet, electrophotographic (laser), magnetic, ionographic, nanographic, and digital offset printing, the first two are the most common. Ink jet printing is characterized by high-quality color images and photographs, but it has a low printing speed, short-lived color prints, and the problem of ink drying in the nozzles during prolonged inactive use of ink jet printing devices. Electrophotographic printing is characterized by high quality and speed of printing, resistance of prints to mechanical damage and a wide range of types of printed materials (paper, film, plastic, cardboard, etc.). This method is also a competitor to flatbed offset printing due to the technological capabilities of printing devices, which have significantly expanded due to the development of digital technologies. Among the disadvantages are the higher cost of equipment and consumables, lower quality when printing photographs, and high energy consumption during toner fixation.

According to the analytical data of ‘Drupa 2023’, the highest growth rate of +18 % is for electrophotographic printing compared to ink jet printing — +8 %; also, publishing

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houses prefer electrophotographic digital printing machines (32%) more than ink jet (16 %) [1]. The functional capabilities of digital printing machines are determined by their design features: the ability to print full-color variable data; automatic adjustment of the machine's actuators; control and support of technological parameters in automatic mode. Equipment manufacturers are trying to optimize and automate the process of manufacturing printed products using quality control units for print runs, built-in post-printing systems, expanding the range of weights and formats of printed material, lineature, resolution, quantityof inks and equipment productivity [2–4].

Technical and technological innovations of digital methods allow them to be used when printing on the surface of a wide range of materials in the manufacture of advertising and promotional products. The classic printing material is paper — coated, uncoated, with a textured surface layer, but cardboard, corrugated cardboard, non-absorbent materials are also popular: various types of films (PP, PET), foil, plastic, self-adhesive film, white and transparent, etc.

Color accuracy is an important indicator of the quality of imprints, which, according to the international standard ISO 12647, is influenced by the type of printed material, its surface and structural characteristics [5].

Research of the quality of color reproduction depending on the modes and printing methods in classical, special printing methods [6–9] confirmed the importance of controlling the thickness of the ink layer, color differences, and the amount of dot gain. The influence of the surface properties of the printed material on the quality of color reproduction was also established [10–12].

Digital printing technologies are characterized by a wide variety of designs of office printing devices — printers, industrial digital printing machines, and a wide range of printed materials; therefore, it is relevant to study the technological capabilities of electrophotographic and ink jet methods on various types of consumables.

Methods

The study analyzed the imprints of advertising and promotional products produced on industrial digital ink jet and electrophotographic printing machines using various printing materials: coated and uncoated corrugated cardboard, cardboard, film, plastic, offset paper and textured paper such as linen (table). Also, various printing modes were used for the digital ink jet printer: matt finished, spot gloss effect, satin finishing, premium printing mode, glossy finishing and high quality printing.

Determination of color parameters of various types of printed materials for full-color electrophotographic and ink jet printing was carried out using the X-Rite SpectroEye spectrophotometer [13] according to the standard [14].

To assess the accuracy of color reproduction of electrophotographic and ink jet imprints, quality indicators were used: color gamut and color distortion values according to the CIE Lab system (ΔE_{2000}) [15].

Results and Discussion

Fig. 1 shows the color gamut graphs in the CIE a*b* system for CMY colors for ink jet and electrophotographic imprints. The presented color gamut graphs in the CIE a*b* system for different imprints were compared with the color gamut constructed from the values of the color coordinates of CMY colors according to the ISO 12647-2 standard [14].

When comparing the color gamut for ink jet prints on uncoated corrugated cardboard (fig. 1, a) with the ISO 12647-2 standard, it is possible to note a slightly increased level of color reproduction when using the 'Satin finishing' and 'Spot gloss effect' printing modes compared to the 'Matt finished' mode. This may be because the print obtained using the 'Matt finished' mode did not have an additional varnish layer applied. In contrast, ink jet prints obtained on coated corrugated cardboard (fig. 1, b) almost completely correspond to the standard color gamut with the except of shades of purple color.

Electrophotographic imprints, especially for non-standard printed materials (fig. 1, c), differ greatly from the color gamut of the ISO 12647-2 standard. Thus, the imprint obtained on plastic has the smallest color gamut, but it completely overlaps the color gamut of the ISO 12647-2 standard, which indicates a general decrease in the saturation of the basic CMY colors while maintaining color balance.

Researched printable materials and digital printing modes

№	Printed material type	Printing mode	Type of digital printer	Additional varnishing
1	Uncoated corrugated cardboard	Matt finished	Ink jet	No
2	Uncoated corrugated cardboard	Spot gloss effect	Ink jet	Yes
3	Uncoated corrugated cardboard	Satin finishing	Ink jet	Yes
4	Coated corrugated cardboard	Premium printing mode	Ink jet	Yes
5	Coated corrugated cardboard	Glossy finishing	Ink jet	Yes
6	Coated corrugated cardboard	High quality printing	Ink jet	Yes
7	Offset printing paper (250 GSM)	—	Laser (electrophotographic)	No
8	Coated cardboard (400 GSM)	—	Laser (electrophotographic)	No
9	Film	—	Laser (electrophotographic)	No
10	Textured paper (linen-type, 80 GSM)	—	Laser (electrophotographic)	No
11	Plastic (80 GSM)	—	Laser (electrophotographic)	No

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As for the imprint obtained on film, the color gamut in volume almost corresponds to the standard one, except for minor deviations in the reproduction of shades of yellow and blue. In contrast, imprints obtained on textured paper such as linen have increased color gamut in warm shades of color (yellow, red and magenta).

The color gamut of standard printing materials for electrophotographic printing (fig. 1, d) has relatively smaller deviations according to the ISO 12647-2 standard, which mainly manifest themselves in the reproduction of cold color shades (blue tint).

According to the analysis of the color gamut values of the studied imprints (fig. 1) and by calculating the area of the color gamut figure in the CIE a*b* system for CMY colors, the volume of the gamut of reproducible colors was determined and compared with the volume calculated according to the ISO 12647-2 standard. For the convenience of analysis, the imprints were grouped by type of material according to the ISO 12647-2 standard into groups with uncoated (fig. 2) and coated (fig. 3).

Analysis of the color gamut in the CIE a*b* system for CMY colors when

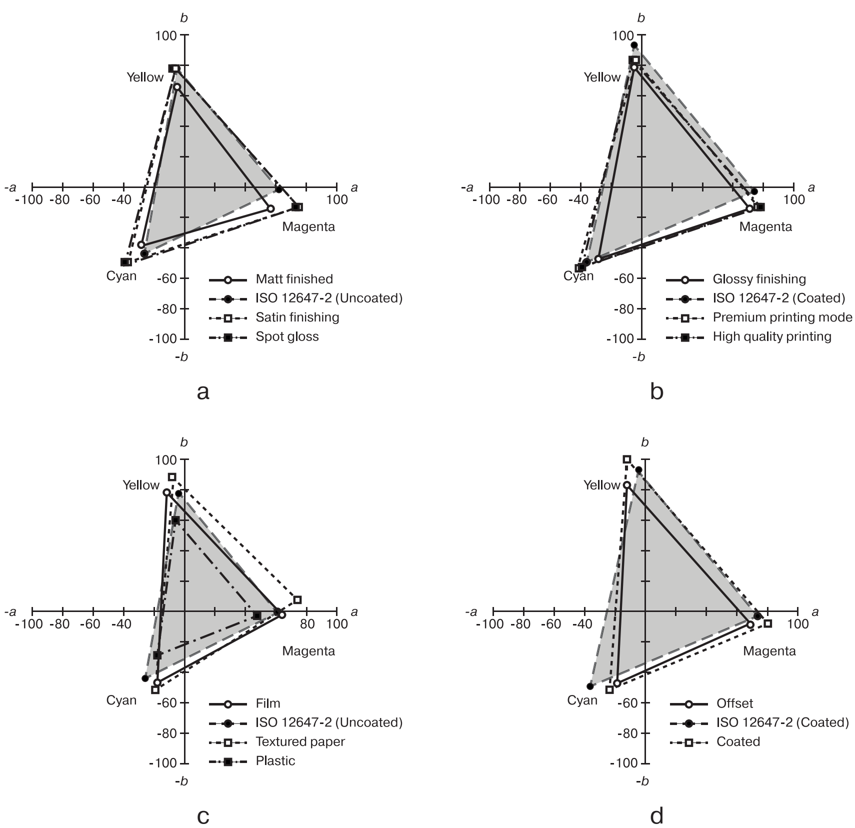

Fig. 1. Color gamut graph in the CIE a*b* system for CMY colors: a, b — ink jet printing on uncoated and coated corrugated cardboard, c, d — electrophotographic printing on various materials

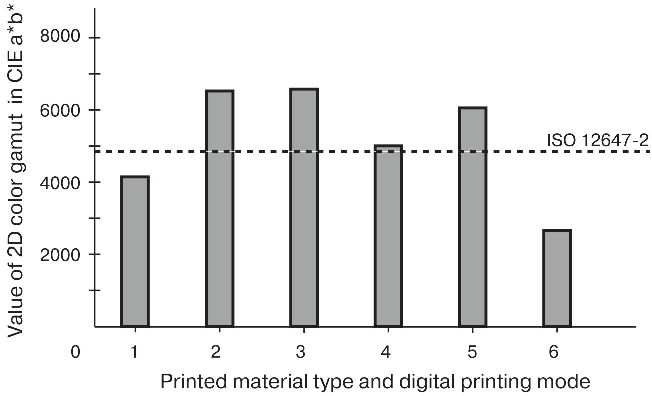

Fig. 2. Comparison of the color gamut in the CIE a*b* system for CMY colors when using different materials and printing modes according to the ISO 12647-2 standard with an uncoated material coating: 1 — Uncoated corrugated cardboard (ink jet 'Matt finished'); 2 — Uncoated corrugated cardboard (ink jet 'Spot gloss effect'); 3 — Uncoated corrugated cardboard (ink jet 'Satin finishing'); 4 — Film (electro-photographic); 5 — Textured paper (electro-photographic); 6 — Plastic (electrophotographic)

using different uncoated materials (fig. 2) indicates significant differences relative to the ISO 12647-2 standard for all samples, except for the film, which correlates with the color gamut graph (fig. 1, c). Significantly higher color gamut indicators correspond to imprints on corrugated cardboard with additional varnish application.

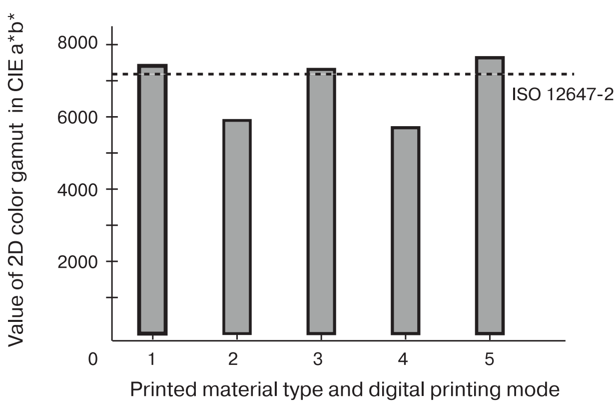

Fig. 3. Comparison of the color gamut in the CIE a*b* system for CMY colors when using different materials and printing modes according to the ISO 12647-2 standard with an uncoated material coating: 1 — Coated corrugated cardboard (ink jet 'Premium printing mode'); 2 — Coated corrugated cardboard (ink jet 'Glossy finishing'); 3 — Coated corrugated cardboard (ink jet 'High quality printing'); 4 — Offset printing paper with 250 GSM (electro-photographic); 5 — Coated cardboard with 400 GSM (electro-photographic)

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Analysis of the color gamut in the CIE a*b* system for CMY colors when using different materials with a coated surface coating (fig. 3) revealed the similarity of a larger number of imprints to the standard. The exceptions are only two samples, for which the differences are no more than 20 % in the direction of reducing the gamut of reproducible colors. While for most samples of materials with an uncoated surface coating (fig. 2) a larger difference of 30–40 % is observed. Moreover, the specified difference may tend to both increase and decrease the gamut of reproducible colors, which is associated with the use of non-typical printed surfaces (film, plastic, textured paper), a variety of printing modes for the ink jet method and the presence of additional surface treatment with varnishing.

Statistical indicators for the magnitude of color differences in the reproduction of the basic colors of the studied imprints were also calculated, which were grouped by type: on materials with uncoated (fig. 4) and coated (fig. 5). Based on the analysis of the quality of reproduction of basic colors according to the formula ΔE_{2000} [16]. The following were calculated: the range of variation, maximum, minimum and average statistical value of the magnitude of color differences.

According to the results of the analysis of statistical indicators, calculated color differences of the base colors of the studied imprints, it was found that the samples obtained on materials with an uncoated surface are less stable in terms of color reproduction accuracy (fig. 4) compared to the samples obtained on materials with a coated surface (fig. 5), regardless of the type of digital printing machine used. This is confirmed by the magnitude of the range of variation of the values of the color differences, which varies for ma-

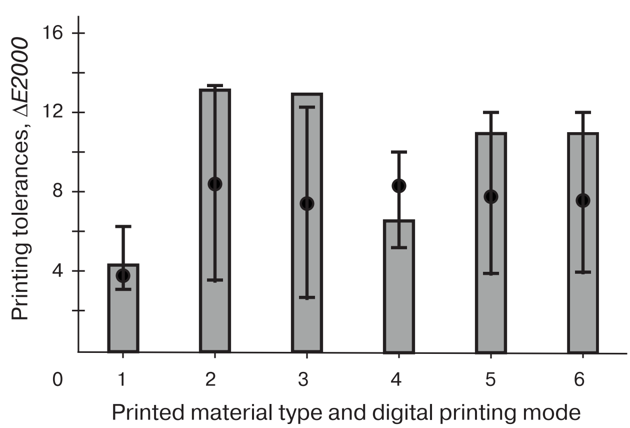

Fig. 4. Statistical indicators of the magnitude of color differences when reproducing the basic colors of the studied imprints with uncoated coating: 1 — Uncoated corrugated cardboard (ink jet ‘Matt finished’); 2 — Uncoated corrugated cardboard (ink jet ‘Spot gloss effect’); 3 — Uncoated corrugated cardboard (ink jet ‘Satin finishing’); 4 — Film (electro-photographic); 5 — Textured paper (electro-photographic); 6 — Plastic (electro-photographic)

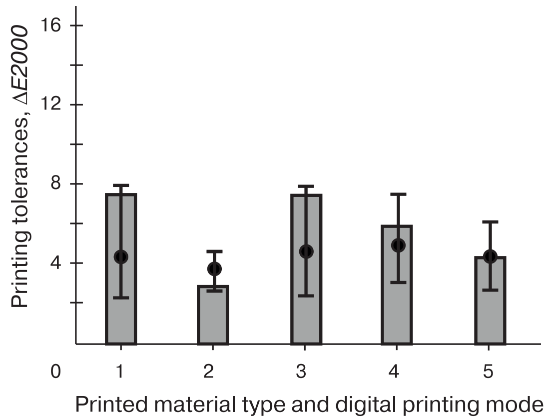

Fig. 5. Statistical indicators of the magnitude of color differences when reproducing the basic colors of the studied imprints with a coating: 1 — Coated corrugated cardboard (ink jet 'Premium printing mode'); 2 — Coated corrugated cardboard (ink jet 'Glossy finishing'); 3 — Coated corrugated cardboard (ink jet 'High quality printing'); 4 — Offset printing paper with 250 GSM (electrophotographic); 5 — Coated cardboard with 400 GSM (electro-photographic)

terials with an uncoated surface within 4…13 ΔE_{2000}, compared to materials with a coated surface, where the change in value is 2.5…7.5 ΔE_{2000}, respectively.

Conclusions

1. In the conducted studies of the accuracy of color reproduction of imprints using electrophotographic and ink jet methods, the color characteristics of the surface of various samples of printed material were analyzed.

2. The influence of the type of printed material on the quality of color reproduction has been established, in particular, on imprints of the electrophotographic method when using non-standard printed materials (plastic, film) — narrowing of the color range, and for imprints on textured paper — increase in the warm shades zone. The color range of standard printed materials for electrophotographic printing has smaller deviations of increase in the cold shades zone, as well as a change of 30–40 % in color differences.

3. The effect of additional varnishing of ink jet imprint on the increased level of color reproduction and expansion of color coverage with uncoated was revealed.

4. Based on a statistical analysis of color differences of base colors, lower color reproduction accuracy was found for imprint with an uncoated surface, regardless of the type of digital printing machine used.

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Проаналізовано колірні характеристики в системі CIE Lab тиражних відбитків електрофотографічного та струминного методів друку. Встановлено вплив характеристик різних типів поверхні задруковуваного матеріалу на точність кольоровідтворення.

Ключові слова: точність кольоровідтворення; тиражні відбитки; електрофотографічний друк; струминний друк; колірне охоплення; колірні відмінності.

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