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RESEARCH INTO THE OPTICAL PROPERTIES OF UV INKJET PRINTING ON POLYMERIC MATERIALS

The paper studies the optical indexes of UV inkjet prints on polymeric materials. It was found that the colour of the printed materials has a critical impact on the chromatic values of colour. A visual evaluation of the corporate colour has revealed contamination with another ink, mainly Magenta, and possible causes of the contamination are presented.

Keywords: UV inkjet printing; colour difference; hue difference; colour accuracy; corporate colour.

Introduction

UV inkjet printing is widely used to print full-colour images on a wide range of materials of various sizes, from large posters to small souvenirs. UV inkjet printing has virtually no restrictions on the choice of print substrates, for example, images can be applied to plastic, metal, paper, glass, wood, leather and other surfaces. Adhesion issues on problematic non-adhesive materials are solved by using special primers in liquid or spray form. The primer applied to the product before printing as an adhesive base between the ink layer and the substrate itself. It is worth noting, that UV inks have high adhesion to many materials, as a rule, primers are used on such materials as polyester, nylon, acrylic and quartz glass, aluminium, copper and materials containing epoxy resin [1]. Modern UV printers are equipped with extended colour palettes, including light process inks, which allow for better reproduction of details in shadows. The application of white ink allows printing on transparent and coloured substrates. A significant advantage of UV printers is the ability to print embossed images, which is achieved through layer-by-layer printing [1].

Growing consumer demands on the quality of printed products, including souvenirs, advertising and gift items, necessitate careful monitoring of image quality indicators. A particularly pressing task is to ensure accurate reproduction of the corporate colour, when branding business products, producing advertising and souvenirs on various materials, which will help to increase the recognition of companies [2]. To ensure optimum image quality and durability, it is necessary to investigate and standardise printing

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processes on polymeric materials in order to obtain the expected quality of imprints in UV inkjet printing.

Standards, regulation of digital printing processes, and recommendations for the use of digital printing technologies in various fields are provided in the international standard ISO/TS 15311-2:2018 [3]. International standards of the ISO 12647 and ISO 15930 series regulate colour parameters, resolution, data exchange formats and terminology related to digital printing. Industry guidelines for profiling, prepress, and colour evaluation of imprints based on material, digital printing type, and viewing distance are provided in the Fogra ProcessStandard Digital 2022 guide [4]. It is noted in [4], that compliance with the recommendations for the production of printed products, taking into account the type of printing machines, printed and consumable materials, will promote the production of imprints of the expected quality.

The study of the quality indicators of large-format inkjet imprints [5] revealed the influence of paper grade and printing modes on the optical density, gradation and colour tone of imprints; as a result, a method for calculating a comprehensive quality indicator was proposed, which would take into account all the optical indicators of imprints and their changes depending on the printing modes in order to determine the optimal one.

The influence of technological factors of inkjet piezoelectric UV technology on the quality of colour reproduction of imprints obtained on different types of printed material was investigated in [5]. According to the results of research [6], it is necessary to: profile the equipment in accordance with regulatory requirements and take into account the type of printed material; carefully select consumables, namely ink for printed materials. It has also been found, that the optical and graphic characteristics of imprints are influenced by the characteristics of inks and surface properties of printed materials, namely the surface microgeometry, which is confirmed by the research of [6]. In the analysed sources [5, 6], the studies mainly concern the effect of different types of paper and only partially PVC plastic, but the effect of the colour of the printed material on the colour reproduction accuracy was not considered in detail.

Given that the range of souvenir products is growing every year, facilitated by the emergence of new types of materials with different textures and colours, there is a need to ensure the accuracy of corporate colours on different surfaces. The development of recommendations aimed at ensuring accurate colour reproduction on coloured polymeric materials will allow manufacturers of promotional products to produce products of predictable quality.

Methods

The research was carried out on a Mimaki UJF-3042FX UV inkjet printer (piezo-jet technology, drop-on-demand, 1440×1200 dpi print resolution). Samples of polymeric materials were chosen for printing: glossy and matte white HIPS polystyrene 3 mm thick; foamed PVC plastics 3 mm thick in black, red, green and blue; transparent acrylic 1 mm thick. Microphotographs of the material samples and their Lab coordinates are shown in fig. 1.

The printing was done with Mimaki UV Ink LH-100, a UV ink designed for printing on tough materials and providing high resistance to physical and chemical effects.

To evaluate the effect of the colour characteristics of the printed materials on the reproduction of the corporate colour, a layout was prepared in which the yellow colour imitates printing in a light corporate colour. The developed layout consists of spot color elements of the following sizes: round — diameter 10 mm, square — 20×20 mm, text — 9 pt, 10 pt, 12 pt, 14 pt. The surfaces selected for the study were printed using two methods: 1. applying the image directly to the printed material; 2. applying the image to a pre-printed white substrate to imitate the colour of paper.

The measurements were carried out on four control fields located around the perimeter of the samples. The values of the following parameters were determined: L (lightness), ΔE (colour difference), a and b (colour coordinates), ΔH (hue difference) and D (density). To evaluate the quality of colour reproduction, we used an X-Rite SpectroEye spectrophotometer (0/45 geometry, 2° viewing angle, D65 light source). A Levenhuk DTX 90 microscope was used to analyse the text reproduction. Figure 1 shows microphotographs of the imprints obtained under the two schemes.

The purpose of this paper is to study the influence of the printed material on the optical indexes of imprints obtained on polymeric materials by UV inkjet printing.

Results

The analysis of the effect of the printed material on the lightness index L when applying the image to samples of materials with and without a substrate expectedly revealed, that the highest lightness values are observed in samples of

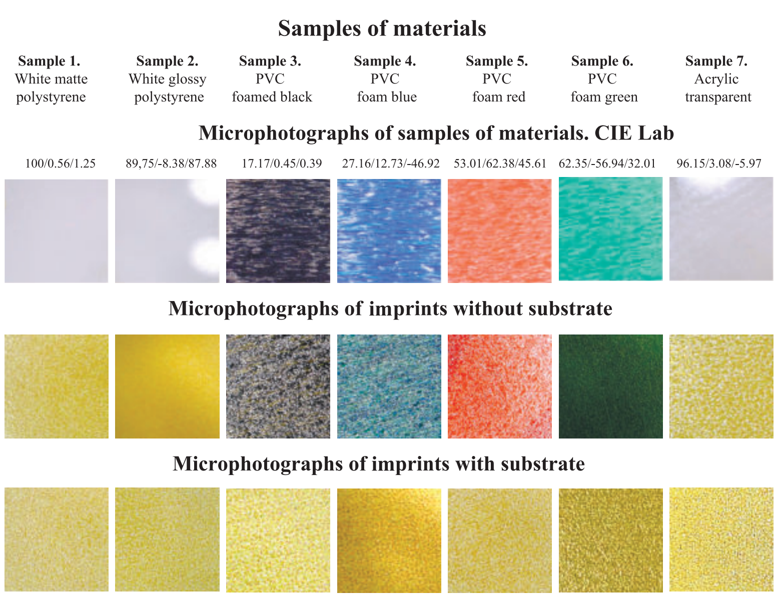

Fig. 1. Microphotographs of material samples and imprints

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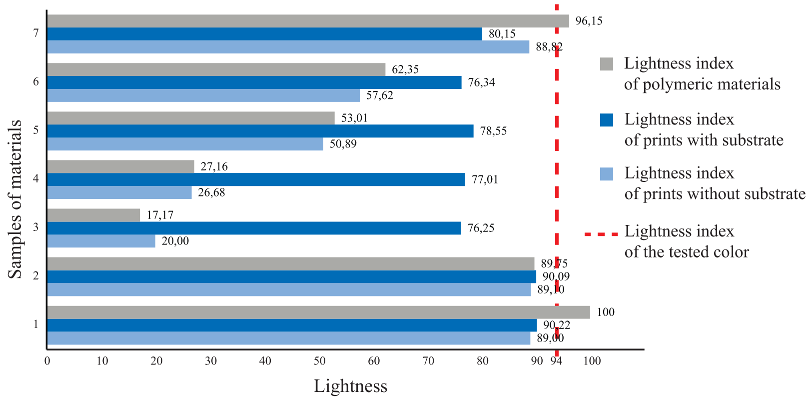

Fig. 2. Influence of the printed material on the lightness index L

white polystyrene on a matte and glossy surface (fig. 2, samples 1, 2). The lightness of the yellow colour under study is 94; when applied to the samples (1, 2) according to the two schemes, the lightness decreases, which can be explained by some contamination of the yellow colour with other colours (see fig. 1), which is typical for inkjet printing [7]. The lowest lightness values, when printed without a substrate, are observed on samples of black and blue PVC plastics (fig. 2, samples 3, 4).

The indicators of colour difference on the studied material samples were determined in two stages. First, the indicators of the yellow colour under study in the digital file (94/-8/105) were chosen as a reference, as shown in fig. 3. On white samples 1, 2, the colour difference on the imprints without a substrate is smaller relative to the imprints with a substrate, which can be assumed to be due to the fact, that white UV inks have a slight shift in colour tone, 10 units, towards blue. The application of a white substrate in one

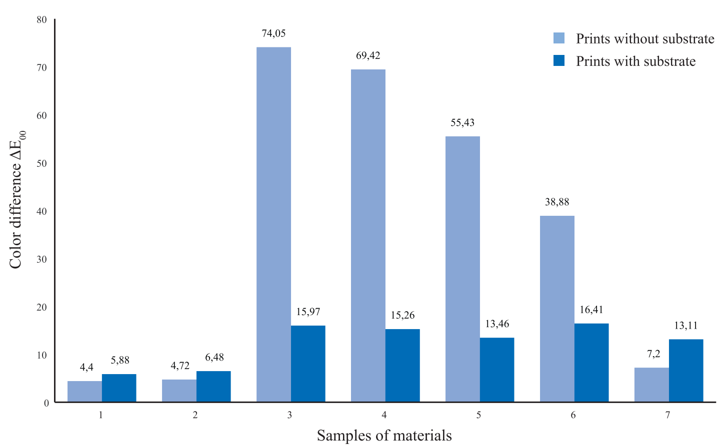

Fig. 3. Effect of the printed material on the colour difference ΔE (reference: colour values in a digital file)

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layer allows to reduce the colour deviation on the coloured samples 3–6 (figs. 3. 4), which contributes to the similarity of the colour under study with the digital file, although visually one can observe the existing shade characteristic of coloured print substrate (fig. 1).

At the second stage of determining the colour difference indicator, an imprint on white matte polystyrene without a substrate (sample 1), which has the closest Lab results to PS2 paper [8], was selected as a reference; the colour difference of sample 1 relative to PS2 is 4.57. The determined colour difference values are shown in fig. 4. The application of yellow to the samples with and without a substrate shows a significant colour difference, especially for dark coloured samples such as blue, red, black and green PVC plastics (fig. 4). Samples 2 and 7 (fig. 4) have acceptable values of colour difference. The colour difference values, when compared to the printed reference, are lower than those obtained when compared to the digital reference.

In addition to determining the accuracy of colour reproduction, the hue difference was assessed. For process inks, the permissible deviations in hue should not exceed 3 [8]. According to the calculations, the hue differences for sample 1 correspond to the standard for offset printing, which indicates, that the colour reproduction is as close as possible to the reference (sample 1 without a substrate) (fig. 5, sample 2). On the coloured samples of materials 3–6, the hue differences are significant. As noted above, the colour of the material has a visual impact on the perception of the hue of the corporate colour under study. Samples 3–6 acquire the characteristic hue of the imprint substrate (fig. 1).

The effect of the printed material on the optical density D is shown in fig. 6. For coloured samples 3–6, the optical density was determined only for samples with a substrate, since the ink layer applied to coloured PVC plastics without a substrate is translucent, and it is not possible to objectively assess the optical density.

Discussion

The studies conducted allow us to state, that UV inks applied in a single layer are not 100 % covering,

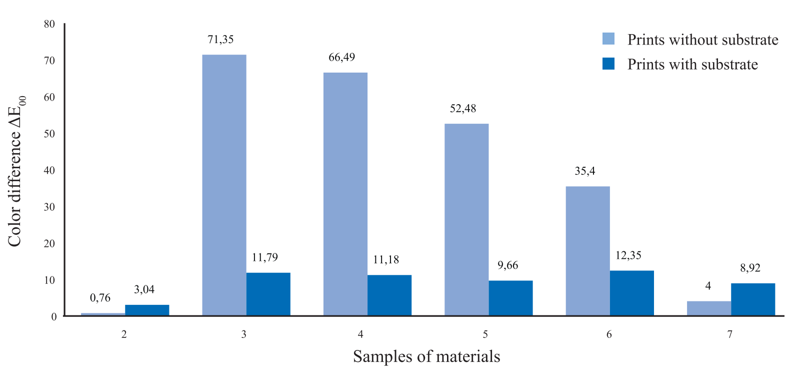

Fig. 4. Effect of printed material on colour difference ΔE (reference: sample 1, uncoated)

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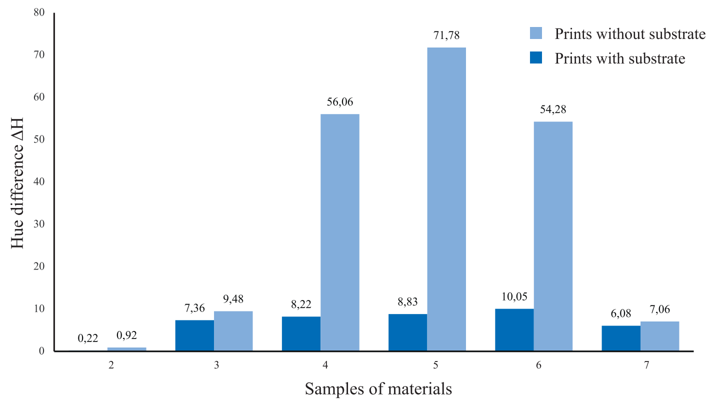

Fig. 5. Influence of the printed material on the hue difference ΔH

and the colour of the print substrate has a critical impact on the chromaticity of the colour. Namely, on sufficiently dark materials, when printing an image without a white substrate, it is impossible to objectively assess the chromaticity indexes of the colour. In addition, the surface of samples 3–6 has micro-irregularities, that are visible to the naked eye, as a result, the imprints obtained without a white substrate are characterized by uneven distribution of the ink layer and low colour intensity (fig. 1). It can also be concluded, that the microgeometry of the surface of the dyed samples does not have a significant impact on colour reproduction compared to the influence of the colour of the print substrate. It should be noted, that the application of a white substrate to samples (3–6), that have colour contributes to an increase in the lightness index (fig. 2), but the applied colour acquires the characteristic hue of the print substrate.

When assessing the accuracy of corporate colour reproduction, the issue of colour difference tolerance is relevant. When printing on non-absorbent materials with digital printing, the tolerances for assessing the accuracy of corpo-

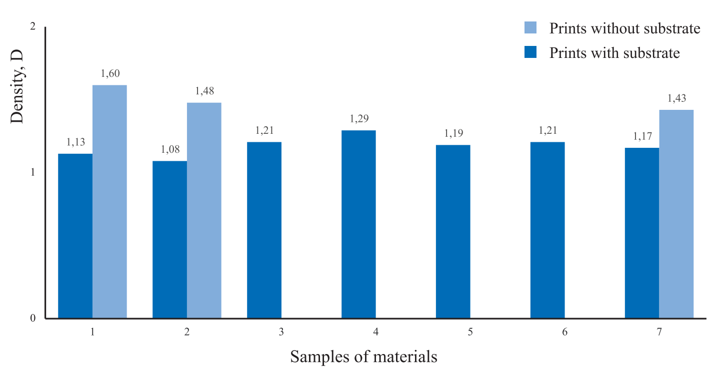

Fig. 6. Influence of the printed material on the optical density D

rate colour reproduction given in [8] can be used as reference values. Therefore, it is necessary to evaluate the colour parameters taking into account, that printing is carried out on materials, that have different Lab coordinates from the typical paper groups specified in the standard; in addition, inks are used for printing, that have different spectral characteristics from process offset inks.

According to the ISO 12647-2:2013 standard [8], the colour difference tolerance according to the 1976 formula (ΔE_{ab}) for process inks in offset printing is regulated to 5 units; according to the 2000 formula (ΔE_{00}), it is up to 3.5 units for CMY, up to 5 units for K. The use of a ΔE_{00} tolerance of 3.5 to evaluate the accuracy of colour reproduction in the printing industry is recommended based on the results of a study by [9].

The use of the ΔE_{00} formula is supported by research conducted in [10] to compare the accuracy of formulas for evaluating colour differences. The authors state, that the calculation using the 2000 formula gives more accurate results and is recommended for determining the colour difference for printed products. In [2], it was found, that the determination of ΔE_{00} when evaluating the difference between the colours of imprints additionally takes into account the effect of lighting when viewing products. Taking into account the analysis, the 2000 formula (ΔE_{00}) was used to calculate the colour difference indicator.

According to the results of research in [11], it was found, that the colour difference indicator is significantly influenced by the white point of the print substrate and the thickness of the ink layer, namely, it is argued, that the thinner the ink layer, the higher the value of ΔE. This statement correlates with the results presented in figs. 3, 4.

The colour difference indicator does not always objectively describe the accuracy of colour reproduction. According to the recommendations of [4], the assessment of colour reproduction accuracy requires a comprehensive approach and includes: selecting a standard for comparison; setting the level of required reproduction accuracy (A, B and C); and taking into account the viewing distance of the imprints. For the spot colour generated by the process ink simulation, the following tolerances on ΔE_{00} for the corresponding accuracy level were determined [4]: for level A, no more than 2.5, B — 3.5, C — 5.5. According to these values, only samples 1, 2, partially sample 7 (without a substrate) can provide acceptable colour reproduction accuracy, provided, that the required accuracy level C is determined (fig. 3, 4).

Based on the results of the analysis of fig. 5, it can be concluded, that one layer of white substrate is not enough for accurate colour reproduction without any hue shift. It can be assumed, that the application of two layers of white ink will allow to obtain acceptable colour reproduction accuracy. According to studies [12], it was found, that the thickness of the ink applied by UV inkjet printing in one layer is 0.1 mm, in two layers — 0.2 mm, i.e. increasing the thickness of the ink layer will reduce the effect of the colour of the print substrate on the reproduction of the corporate

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colour. In this work, the study of colour values when applying two layers of white ink was not carried out, this issue requires additional research. The obtained data on ΔE_{00}, ΔH for sample 7 are ambiguous and require additional research, since the determination of colour values for sample 7 was carried out on a stack of white paper sheets, so its influence may be partially present in the measurements.

The study of the optical density of imprints showed, that when applying the corporate colour to samples without a substrate, the optical density is higher, which is explained by the lower lightness of the imprints (fig. 6). This statement is also confirmed by the data for samples 3–6, i.e. the higher the lightness, the lower the optical density. In general, the use of the optical density index is not representative for assessing colour reproduction on non-absorbent painted surfaces.

Fig. 7 shows photographic images of the printed text on the samples in two schemes: without and with a substrate. The imprints clearly show white halos around the texts, i.e. the white substrate itself. Mismatching of several ink layers can occur if the digital device is not set up properly, i.e., calibration is required. For UV inkjet printing, a minimum line thickness of 0.16 mm is recommended. According to the

Fig. 7. Photographic images of the printed text on samples 1–7

equipment specification, the alignment tolerance is ±0.2 mm. During the study, it was found, that the misalignment was 0.12 mm, which is within the specification tolerances, but a white outline was visually observed. This should be taken into account when preparing layouts for printing with a white substrate, by setting the trapping contour and the correct dimensions of graphic elements.

Imprints produced with yellow ink have some contamination with other ink, mainly magenta, which may indicate, that the printhead nozzles are dirty or have failed. This may be due to the use of low-quality ink. To prevent this problem, the cartridge should be cleaned periodically [13]. On samples 1, 2 without a substrate, the printed text is clearly visible, while on other samples, especially on 3–6, without a white substrate, the text is barely visible (fig. 7). Dark and transparent materials undoubtedly require an additional application of a white substrate to achieve the required colour accuracy.

Conclusions

1. According to the results of the research, it was found, that when printing on white surfaces with UV inkjet printing, it is possible to achieve the required colour accuracy when printing without a white substrate. At the same time, dark and transparent materials require an additional application of white ink (substrate) to ensure the required colour accuracy. It was also found, that a single layer of white ink is not enough to accurately reproduce the colour without an existing hue shift. It is assumed, that the application of two layers of white ink will allow to obtain acceptable colour reproduction accuracy, which requires additional research.

2. Compliance with printing technology plays an important role in the production of UV inkjet products, including: layout preparation, creating trapping contours when printing with a substrate; proper equipment calibration; selecting high-quality UV inks, checking nozzles and the accuracy of positioning the print material. Failure to comply with these parameters can lead to various defects, such as misalignment of the substrate and image, blurred edges, pale areas, and dots of a different colour on the print.

3. To evaluate the accuracy of corporate colour reproduction in the production of branded business gifts, it is necessary to take into account the colour of the print substrate and the typical lighting conditions for viewing the finished product.

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В роботі досліджено оптичні показники відбитків струминного УФ-друку на полімерних матеріалах. Встановлено, що колір задруковуваного матеріалу чинить критичний вплив на хроматичні показники кольору. Візуальна оцінка досліджуваного корпоративного кольору встановила наявне забруднення іншою фарбою, в основному пурпуровою; наведено можливі причини виявленого забруднення.

Ключові слова: струминний УФ-друк; колірна відмінність; колірний тон; точність відтворення кольору; корпоративний колір.

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