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STUDY OF THE INFLUENCE OF THE SURFACE STRUCTURE OF THE SUBSTRATES ON THE IMPRINTS QUALITY

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Abstract

Modern printing technologies allow the use of a diverse range of materials for printing to satisfy the requirements of the most demanding consumers. However, the quality of the imprint is not always satisfactory. Of course, there can be many reasons: non-observance of technological printing modes, problems related to setting up the operation of the main and auxiliary mechanisms of the printing machine, problems of transporting material through printing and inking units, etc. One of the problems of obtaining a high-quality imprint in all printing methods is compliance with certain technological requirements regarding the selection of the properties of the printed materials, in particular their surface. Properties of the printing base surface are one of the most important factors affecting the completeness of the image transfer and the appearance of the imprint.

Based on the methods of system analysis, hierarchical groups of imprint quality indicators in flexographic and digital printing methods, which ensure high imprint quality, are singled out. Accordingly, studies of the surface topography of imprints on paper and cardboard with and without a chalk coating, as well as on film materials (in flexographic printing technology) were conducted.

The surface topography of imprints on various materials was experimentally investigated. A change in the morphological structure of the substrate surface before and after printing was revealed. It has been studied that the presence of a chalked coating, which changes the parameters of roughness and the area of peaks and valleys on papers and cardboards, has a significant effect on the microgeometry of the surface. The method of surface treatment of film materials also affects the topography of imprints surface. It has been confirmed that with an increase in the number of surface coating layers on the substrates, the roughness parameter decreases significantly. The morphological structure of the surface of the materials before printing is preserved on imprints, but its smoothing is observed to a greater or lesser extent depending on the printing method used to obtain the printed image. Also, the indicators of the surface structure of the

imprint are affected by the characteristics of inks, varnishes, the method of imprints finishing, for example, by the lamination. This is confirmed by the results of electron microscopy.
Based on the results of experimental studies and taking into account the ISO model, a conceptual model and algorithm for the functioning of imprints quality assurance system were proposed, which take into account the problems associated with the dependence of the parameters of the surface structure of printed materials.
***Keywords**: imprint, quality, substrate, surface structure, system analysis.*

Introduction

Today, consumers of all countries of the world put forward increased demands for the decoration of packaging and sanitary-hygienic products. Therefore, printing companies use various printing and finishing technologies to meet their requirements. A wide and diverse assortment of packaging materials prompts manufacturers to study in detail all possible factors affecting the quality of imprints and their decoration. Lamination is a popular method of imprints finishing (Havenko, Dovhanych 2021).

The Ukrainian market of sanitary and hygienic products in terms of assortment and number of segments practically does not differ from the European or American one, but at the same time it is disproportionate – according to various estimates, from 70 to 80% is made up of toilet paper (Andrievska 2012; Andriyevska 2010), ("Market of sanitary" 2022), (Kalashnyk, Moroz 2008). And the products of this category of goods are very diverse and the need for them is growing every year, especially napkins. In addition, product consumers prefer printed napkins, which often become an attribute of celebrations, anniversary events, etc. That is why research on the quality of printing on napkins is relevant. In particular, such studies relate to the determination of densitometric and colorimetric indicators of images on imprints; identifying factors that affect the quality of this type of product.

Methodology and equipment

The aim of the study was to determine the morphological structure of the materials surface of imprints on them, obtained by flexographic and digital printing methods, and systematize factors influencing densitometric, colorimetric indicators of the quality of printed images.

The objects of the study were flexographic and digital imprints on UPM Digi Color cardboard with a grammage of 200–300 g/m^2 and two-layer paper of Huchtemeier Papier Gmbh with a width of 33×33cm.

UPM Digi Color paper (Finland) is a high-quality pure cellulose paper for digital printing, designed specifically for dry toner devices with sheet or roll paper feed (Table 1).

Table 1. Technical characteristics of UPM Digi Color papers (Finland)

Density (ISO 536), g/m	3
Fullness (ISO 534), g/m	1,05
Brightness D65, (ISO 2470-2), %	114,0
Whiteness CIE	170,0
Opacity (ISO 2471), %	99,7
Roughness	50

Huchtemeier Papier Gmbh tissue paper is made of bleached cellulose fibber, where all layers of the product are fixed. The paper is not corrugated, not chalked, not embossed, not perforated, without watermarks, without coating and not impregnated with special substances, does not contain fibbers obtained mechanically (Table 2).

Table 2. Characteristics of tissue paper Huchtemeier Papier Gmbh

Indicator	Value	Test method
Tensile strength	900–1000–800	SCAN P 44:81
Tensile strength	450–500	SCAN P 44:81
Weight	18,5±0,5	ISO 536
Thickness	2	SCAN P 66
Colour	white	Visually
Pliability	17	On
Humidity	5,5	On

The MICRO MEASURE 3D station profilometer, whose action is based on a non-contact method, was used to study the morphology of the surface of cardboard, papers and imprints on them. The surface structure of the substrates and imprints on them was studied on the AniCam installation of the company TROIKA Systems Limited, equipped with a 24-bit colour camera with a resolution of 640×480 pixels and a field of view from 1.25×0.92 mm. A three-dimensional image of the surface structure was obtained from the analysis of digital photographs of the surface of the substrate and the imprint

(measurement accuracy is ±1%). A test form was created to determine the densitometric and colorimetric characteristics of imprints (Fig. 1). A Konica Minolta FD-5bt spectrophotometer and a GRETAG SPM50 densitometer were used to study imprints. The values of optical densities and colorimetric indicators were compared with the values determined by international ISO standards (ISO 12647-6, 2017), (ISO 12647-2, 2008).

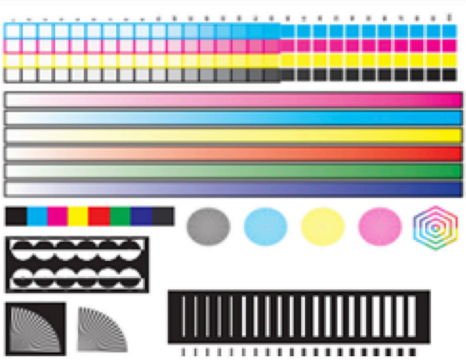


Fig. 1. Scale for studies of imprint quality

Imprints were obtained on a digital printing machine XEROX 700i Digital Color Press and a flexographic machine OMET TV 503 Lecco. Environmental water-soluble flexographic inks of the company Aquaflex Plus were used to apply the image by the flexographic printing method. Before use, they were mixed well and the required amount of water was added to obtain the required viscosity. The printing viscosity depends on the speed of the machine, so the ink must be diluted 10–20% with water to obtain the following range of values: 17–20 seconds. For laminating imprints, Lamiroll Glossy polypropylene film (PPL) with a thickness of 24 μm and a RL300 model roll laminator was used.

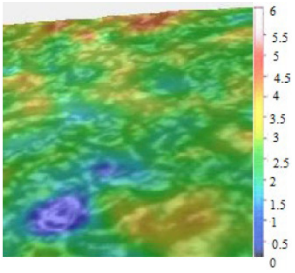
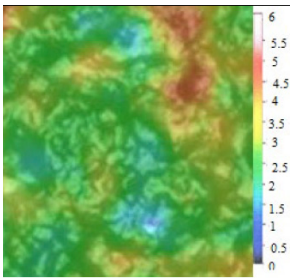
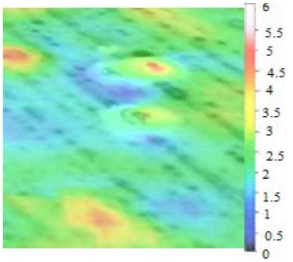
Presentation of research results

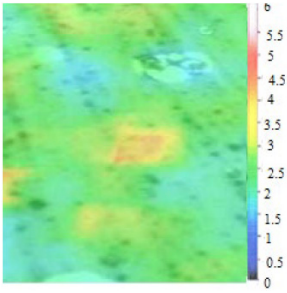
The surface topography of imprints on various materials was experimentally investigated. A change in the morphological structure of the substrate surface before and after printing was revealed. It was found that the presence of a chalked coating, which changes the parameters of roughness and the area of peaks and valleys on papers and cardboards, has a significant effect on the surface microgeometry (Table 3).

The analysis of tabular data and profilograms shows that the imprint on the cardboard is characterized by a large degree of unevenness, an uneven

distribution of surface structure elements, which is confirmed by the roughness parameter Ra = 0.43 μm, which indicates a highly developed micro- and sub-microstructure of the surface. Therefore, the conducted studies confirm that investigated imprints have different microgeometry of the surface.

Table 3. Results of studies of the morphology of substrate surfaces and imprints on them

Substrate	Weight, g/m^2	The nature of the surface	R_a, μm	Rz, μm	S_{peaks}, μm^2	$S_{valleys}$, μm^2
Paper UPM Digi Color	300	 Not printed	0,74	5,72	892	802
Paper UPM Digi Color	300	 Digital imprint	0,65	5,94	904	786
Tissue paper	80	 Not printed	0,48	4,64	686	712

Sub-strate	Weight, g/m^2	The nature of the surface	R_a, μm	Rz, μm	S_{peaks}, μm^2	$S_{valleys}$, μm^2
Tissue paper	80	 Flexographic imprint	0,32	5,86	748	648

The values of L* a* and b* measured for the colour gamut and the value of print chrominance are shown in Fig. 2 below. We can see the difference in colour transfer between different types of printing with the regulated colour coordinate according to ISO 12647. The wider the colour gamut, the greater the value of L* a* and b*.

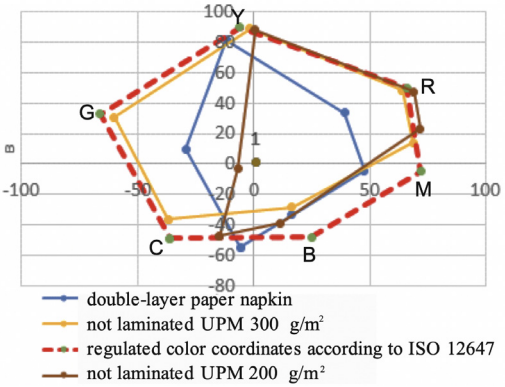


Fig. 2. Correlation of colour characteristics of studied imprints

Fig. 3 shows the values of the colour difference of CMYK, determined on the test scale (80%).

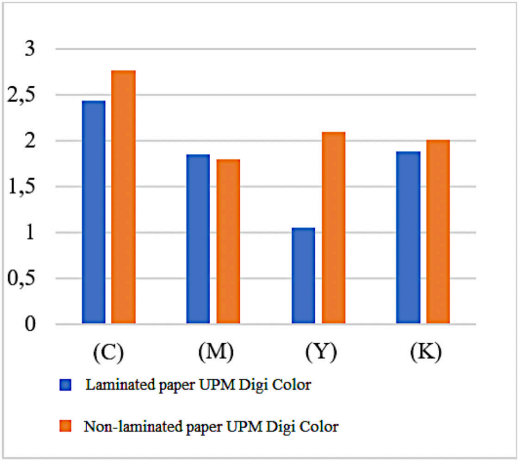


Fig. 3. CMYK colour difference diagram of digital prints

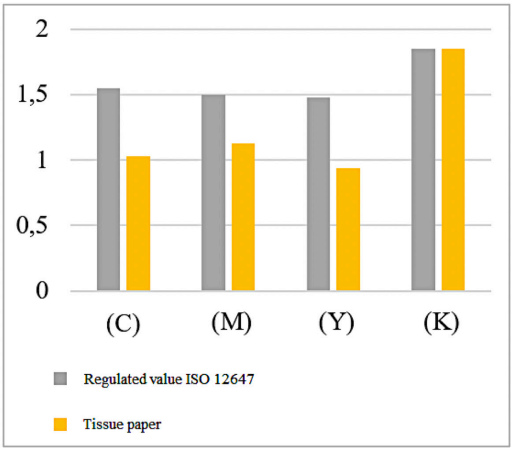


Fig. 4. CMYK colour difference diagram of flexographic imprints on tissue paper

As the research results show, the values of the colour difference of imprints on tissue paper, formed with contour ink, coincide with the standard ones. Deviations of 15–25% from the standard values have imprints of other CMY colours, which are placed in the Yellow > Cyan > Magenta range.

Conclusions

1. The structure of the surface of the unprinted material is repeated on the investigated digital imprints.

2. The topography of the substrate surface affects the quality of the formed images, as evidenced by the values of the optical and colorimetric indicators of imprints.

3. Lamination affects the quality of imprints, in particular, reduces their colorimetric indicators.

4. Flexographic printing on tissue papers reproduces tonal images differently for CMYK colours

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