Investigation of Resistance to Mechanical Effect of Braille Formed on Different Materials

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Resistance to mechanical effect of Braille dot surfaces formed using screen printing on different materials (paper, paperboard, polymer, textile, Al foil) was investigated. It was obtained that according to the type of material, Braille dot height change after period mechanical effect is different. It was determined that screen printing is not suitable for forming of Braille on coated paperboard (Arktika) because the dots are least durable and can be hard to read for the blinds.

Applying the specialized polarimeter equipment, qualitative analysis was carried out of stresses originated in paperboard during embossing of Braille font. Based on the analysis findings the stamps of enlarged circulation could be designed.

Keywords: Braille, Braille dot, mechanical effect, polarimeter equipment, screen printing.

1. INTRODUCTION

Depending on materials used for packaging, Braille could be formed in different types: screen or digital printing and embossing [1]. At this moment embossing Braille are used only for the production of pharmaceutical paperboard packaging but it would be appropriate to use Braille for food, clothing and chemical products packaging or for labels of different materials (polymer, textile, Al foil and others). This would help the blind to integrate into society better, as use of Braille in their environment, as well as on a variety of goods packings or labels, is one of the ways of a full-fledged integration into the social life for people with visual disabilities.

The most important Braille parameters are height and distances between dots and their diameters [1, 2]. Each separate parameter and whole of it has great importance for Braille reading, because even the absence of single dot or inappropriate formation can change the meaning of information [3 – 5]. Clarity of Braille reading depends on surface of material type it is formed on [6]. Because surfaces of materials differ in their topography and are perceived differently in the senses visually impaired human. Thus number of studies has been done. The results show that the friction coefficient between the human finger and different types of surfaces explain the unique nature of these senses [7]. However, the scientific literature does not deeply examined problems of Braille made on different materials.

So it is important to choose materials and geometrical parameters of Braille dot properly, which and after some mechanical effect should remain easy readable for the blind.

The change of Braille geometrical parameters was already determined in our previous studies [8, 9]. The experimental tests have shown that depending on the paperboard type, composition and paperboard surface properties, packages surface with Braille wears differently. Also it was obtained that the higher resistance to mechanical effect has the packages with Braille made from cellulose paperboard (Alaska, Arktika (producer – International Paper)) and the packages made from recycled paperboard (Mirabell (MM karton)) are less resistant [8, 9].

The quality of Braille is affected not only by the properties of the paperboard but on properly selected stamp as well. During Braille forming when the stamp is contacting with different type of materials, stresses appear in a contact zone, which originate configuration and size of Braille dot geometrical parameters [10, 11]. Important place in this process takes the circulation of Braille stamp.

The aim of this paper – expand the possibilities of Braille application on various materials (paper, paperboard, textile, Al foil) determining the resistance to mechanical effect of Braille dots formed on different materials using screen printing. Also to provide the means allowing to enlarge the circulation of stamp used for Braille embossing.

2. EXPERIMENT EQUIPMENT AND METHOD

For the testing of mechanical effect, different materials (paper, paperboard, polymer, textile, Al foil) were used, on which Braille was formed using screen printing and plastisolic clear inks. Different materials were chosen having in mind that they could be used for packaging or labels with Braille. Materials characteristics and applications area are given in Table 1.

For the determination of Braille geometrical parameters change under cyclic mechanical effect Oser method was used (Fig. 1). During the experiment, planetary motion for the sample was given and linear speed of every sample is the same. Using this experimental

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device for investigation of mechanical abrasion, the sample holder was loaded by 200 g weight and the linear speed was chosen 0.47 m/s and the term of mechanical abrasion was changed from 1 min to 60 min. The samples were exposed to mechanical force and at stated intervals (from 1 min to 60 min) the measurements of Braille dots heights were carried out. The measurements of Braille dot height and others parameters were carried out with Braille Dot Checker (BRAI³). During first five minutes of abrasion, the samples were measured minutely, later every five or ten minutes.

Table 1. Materials characteristics of print-outs with Braille

No.	Material type	Name, characteristic (producer)	Employment
1.	Paperboard	Arktika, GC-1, 250 g/m^2 (International Paper)	Pharmaceutical, food packaging
2.	Paperboard	Mirabell, GD-2, 250 g/m^2 (MM karton)	Pharmaceutical, food packaging
3.	Paper	Coated, Polaris, 115 g/m^2 (Torraspapel SA)	Candy, chocolate packaging
4.	Paper	Uncoated, Munken Pure, 90 g/m^2 (Arctic Paper)	Candy, chocolate packaging, books, calendar
5.	Textile	100 % cotton (Klasikinė tekstilė)	Clothing labels
6.	Textile	100 % polyester (Liningas)	Clothing labels
7.	Polymer	PP, adhesive (UPM Raflatac)	Adhesive labels
8.	Al foil	Aluminum (Al) and aluminum oxide (Al_2O_3) (Aluflexpack)	Food cup caps

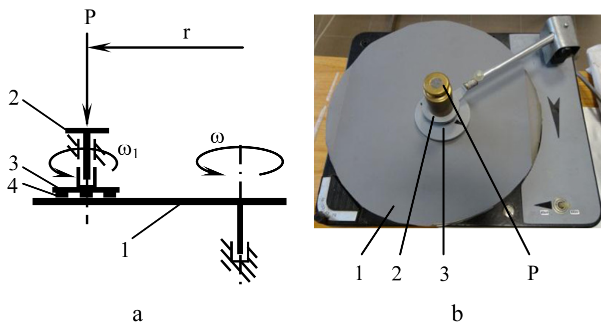


Fig. 1. Experimental equipment kinematic scheme (a) and equipment view (b) of Braille resistance to mechanical effect: 1 – disc; 2 – holder, 3 – sample claim diskette; 4 – samples, *P* – load, ω, ω_1 – angular speed of disc and samples diskette

During forming Braille using embossing, the quality of elements is affected by the contact of stamp with material. Using polarimeter method the distribution of stresses was determined in the contact zone of embossed material. The experimental tests were carried out using methodology, wich was already described in paper [11]. The scheme of the experiment and equipment is presented in Figs. 2 – 4. Glass testing plate having the properties of optical isotropic material was used for the determination of stresses. (Fig. 2, position 1). For the samples two following types of paperboard were selected: Arktika GC-1 and Alaska GC-2, which technical characteristics are given in Table 2. During the test, stress distribution originating during embossing in the stamp was determined (stamp – plane) when the diameter of contact point – 1 mm, stamp is illustrated in Figs. 2 – 3.

By loading optically isotropic material, stresses appear in it, causing optical anisotropy. When wave of polarized light falls on a surface in an isotropic environment, two refracted waves of different polarization occur in the environment, propagating in different directions at uneven speeds. The phenomenon of ambivalent beam break is identified in polarized light [12 – 14].

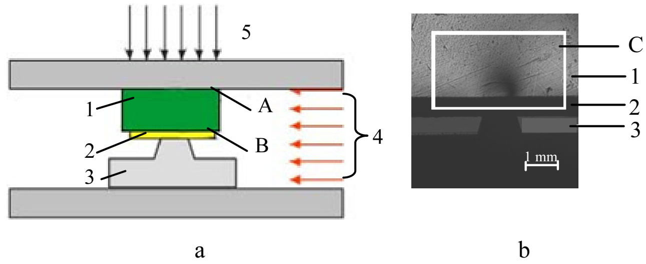


Fig. 2. Simplified scheme of the experimental test (a) and photograph of stress distribution (b): 1 – transparent, optically isotropic material; 2 – paperboard sample; 3 – stamp; 4 – direction of polarized light beam, 5 – direction of pressing load; A, B – contact zone, C – stress distribution zone

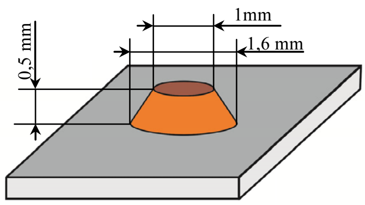


Fig. 3. Geometric shape of the embossed stamp

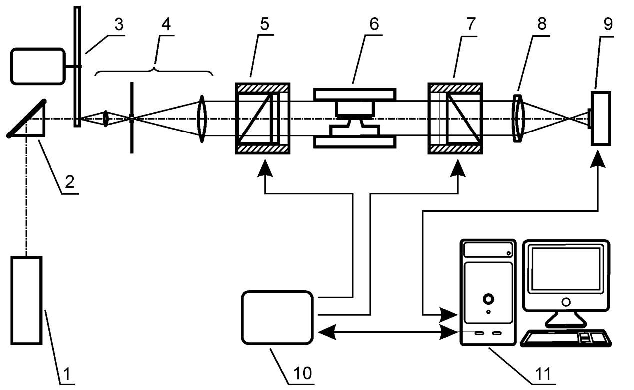


Fig. 4. Functional scheme of imaging polarimeter. 1 – laser, 2 – mirror, 3 – coherence scrambler, 4 – beam expander, 5 – circular polarizer, 6 – sample section (see Fig. 3), 7 – analyzer, 8 – objective lens, 9 – CCD camera, 10 – step motor controller, 11 – PC

Table 2. Paperboard technical characteristics [18]

No.	Parameter	Arktika GC-1	Alaska GC-2
1.	Paperboard mass, g/m^2	250	250
2.	Thickness, μm	468	480
3.	Max deformation after the loading, %	6.78	7.53
4.	Set after the loading, %	0.92	1.71

In a solid, homogeneous transparent optical range medium originating mechanical stresses could be measured using polarimetric method [13]. Under mechanical stresses σ_μ constant B_i (or refractive index n, when $B_i = (1/n^2)_i$) of optical polarization tensor components changes the value [15]:

$$\Delta B_i = B_i - B_i^0 = \pi_{i\mu}\sigma_\mu \,, \qquad (1)$$

where $\pi_{i\mu}$ is the fourth rank piezooptic tensor, B_i and B_i^0 – components of optical polarized constants tensor, of strained and unstrained samples respectively. In case of none zero piezooptic coefficients and respectively chosen sample geometry, the parameters of indicatrix change, thus the phase difference ψ of own waves of light, passing through tested sample, changes [16]. The light intensity passed through the system circular polarizer-sample-linear polarizer could be described:

$$I = \frac{I_0}{2}\{1 + \sin\psi \sin[2(\alpha - \varphi)]\}\,, \qquad (2)$$

where I_0 and I are the intensity of incoming and outcoming light, respectively; $\psi = 2\pi\Delta n d/\lambda$ is the phase difference, which originates under the influence of mechanical stress, λ is the light wave length, d is the sample thickness, Δn is the optical birefringence, which appears under the influence of mechanical stress, φ is the rotation angle of optical indicatrice, α is the orientation angle of analyzer [17].

In case of mechanical model, which relates tensor's stress components σ_μ with mechanical force added to the sample, stresses distribution in the stamp (or matrix) could be reproduced by using the data processing of polarimetric measurements.

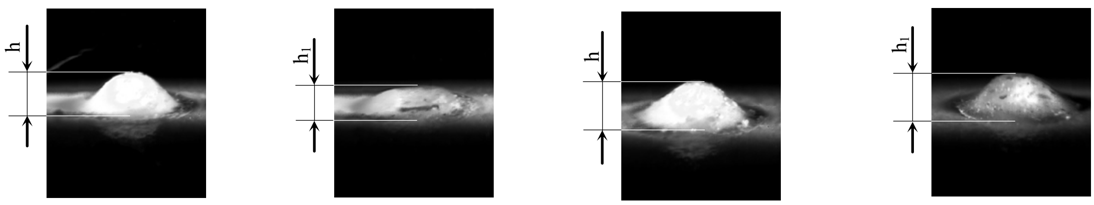
The distribution following of phase difference in the tested sample was obtained in the way: samples (Fig. 2; Fig. 4, position 6) was placed in the polarimeter (Fig. 4) and subjected by 101.91 N force and later, after processing the 2-D distributions, $I(\alpha)$ were obtained ($\alpha = 0^\circ - 180^\circ$ with step 4.5°).

3. RESULTS AND DISCUSSION

The digital images of surface resistance to mechanical effect of Braille dot formed using screen printing on different materials (paperboard, paper, textile, polymer, Al foil) are shown in Figs. 5 – 8.

The measurements of Braille dot height was carried out before experimental test and after the mechanical effect at the fixed intervals (from 1 min to 60 min). The presented digital images are before the experimental start and after max mechanical effect time, i. e., 60 min or 1692 m length of mechanical effect.

From the digital Braille dot images (Fig. 5 – 8) it could be seen that after mechanical effect (60 min) Braille dot height decreased 12 % – 45 % from the initial height.



a b c d

Fig. 5. Digital images of Braille dot on paperboard Arktika 250 g/m² (a, b) and Mirabell 250 g/m² (c, d) when Braille dot height before experimental test $h = 0.31$ mm (a), $h = 0.29$ mm (c), Braille dot height after 60 min of mechanical effect $h_1 = 0.17$ mm (b), $h_1 = 0.25$ mm (d)

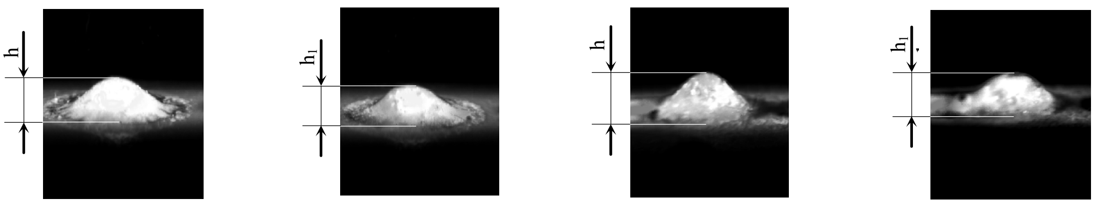


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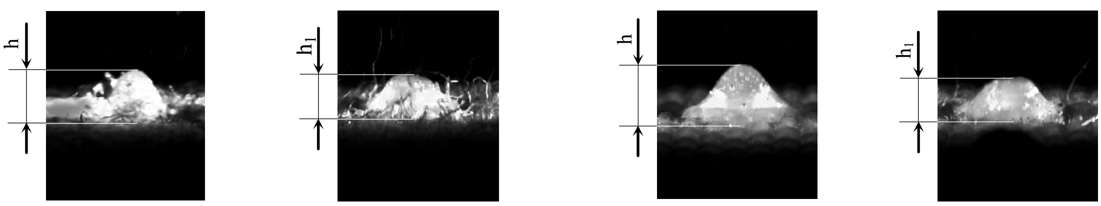
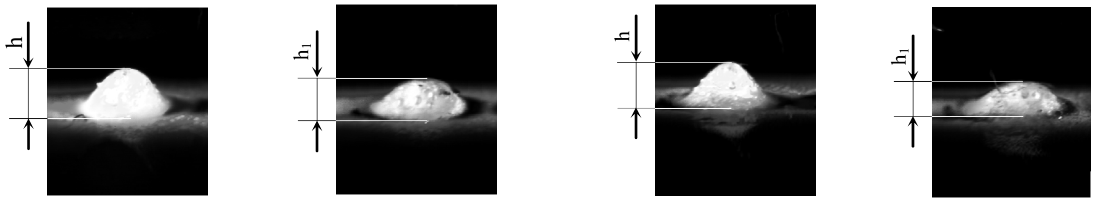
Fig. 6. Digital images of Braille dot on chalky paper Polaris 115 g/m² (a, b) and offset paper Munken Pure 90 g/m² (c, d) when Braille dot height before experimental test $h = 0.34$ mm (a), $h = 0.40$ mm (c), Braille dot height after 60 min of mechanical effect $h_1 = 0.30$ mm (b), $h_1 = 0.31$ mm (d)



a b c d

Fig. 7. Digital images of Braille dot on textile 100 % cotton (a, b) and 100 % polyester (c, d) when Braille dot height before experimental test $h = 0.44$ mm (a), $h = 0.42$ mm (c), Braille dot height after 60 min of mechanical effect $h_1 = 0.32$ mm (b), $h_1 = 0.30$ mm (d)



a b c d

Fig. 8. Digital images of Braille dot on polymer PP and Al foil when Braille dot height before experimental test $h = 0.39$ mm (a), $h = 0.37$ mm (c), Braille dot height after 60 min of mechanical effect $h_1 = 0.26$ mm (b), $h_1 = 0.27$ mm (d)

From the graph (Fig. 9) we see, that the largest influence of mechanical effect takes place during first five minutes, i. e. at 141 m of path length of mechanical effect. At that time the tops of Braille dots, which are less resistant to mechanical effect, are affected. Such results are observed both testing Braille printed using screen printing (see Fig. 9, position 1 – 8) and comparing with the previous investigations [8, 9] in case of embossed Braille (see Fig. 9, position 9 – 10).). The graph shows that height of the Braille dot depends on the path length of mechanical effect. It was ascertained that according to material, on which the Braille was printed, dots wear differently, as plastisol ink diffuses into different material differently, because plastisol ink, during printing due different interaction of materials macromolecules and structural properties (porosity) adhere to material surface differently. It was determined that alternation of Braille dot height after 60 minutes, i. e. after 1692 m of mechanical effect way length is different: the dot height formed on paperboard Arktika decreased by 45 %, paperboard Mirabell – 14 %, textile cotton – 26 %, polyester 29 %, textile – 27 %, paper uncoated – 23 %, coated – 12 %, polymer – 33 %, Al foil – 26 %, from the initial Braille dot height value. Comparing the change after the mechanical effect of Braille formed on paperboard using screen printing with the embossed Braille it was determined that Braille formed on paperboard (Alaska) made from cellulose and chemical termomechanical pulp and using embossing are more durable [8, 9]. But Braille dots formed using screen printing on recycled paperboard (Mirabell) are significantly durable. These results can be explained by the fact that plastisolic inks of screen printing diffuse into the material and are mechanically bonded. After the mechanical effect the change of decrease of Braille dot height are clearly seen for nonporous with flat surface materials.

According to these findings the suitable forming type on different materials of Braille could be selected.

From the given graph (Fig. 10) it can be seen, that when duration of mechanical effect changes (60 min given 1692 m. mechanical effect way length), not only the height of embossed Braille dot decreases but diameter of it also slightly increases. So distance changes between the dots. These changes are caused by applied mechanical force, which compresses the prominent elements formed with plastisolic inks. As plastisolic ink is a polymer, so it is mechanically deformed when the outer mechanical force is bigger than intermolecular. Forming Braille with embossing, the quality of elements during embossing process is affected by the contact of the stamp and material. After the test according to the polarimetric method given findings of the stresses distribution testing different type of paperboard specimens with Braille are shown in the digital images (Fig. 11). Obvious differences can be seen, because the tested paperboards have different structure. In this case the images are taken using circularly polarized light.

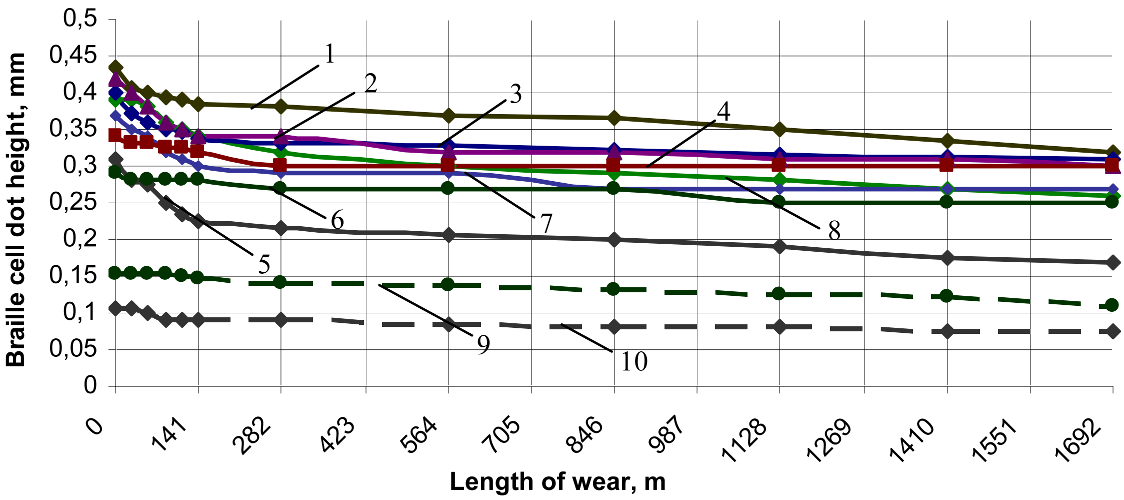


Fig. 9. Braille dot diameter change under different mechanical effect way length (abrasion time – 60 min) when Braille is formed using screen printing on different materials: 1 – on textile/cotton, 2 – on textile/polyester, 3 – on paper/uncoated, 4 – on paper/coated, 5 – on paperboard/Arktika, 6 – on paperboard/Mirabell, 7 – on Al foil, 8 – on polymer PP, when Braille is embossing on different materials: 9 – on paperboard/Mirabell, 10 – on paperboard/Alaska

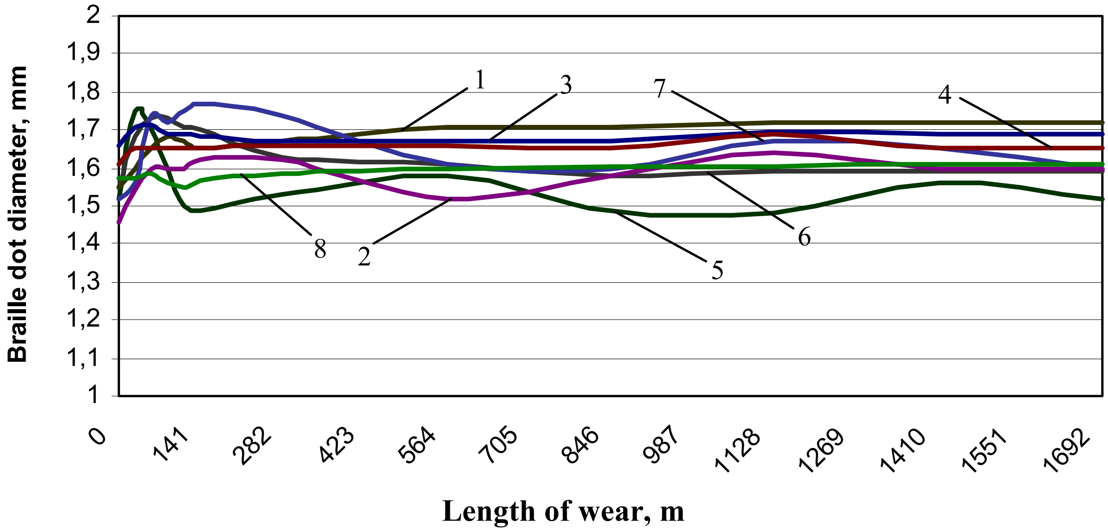
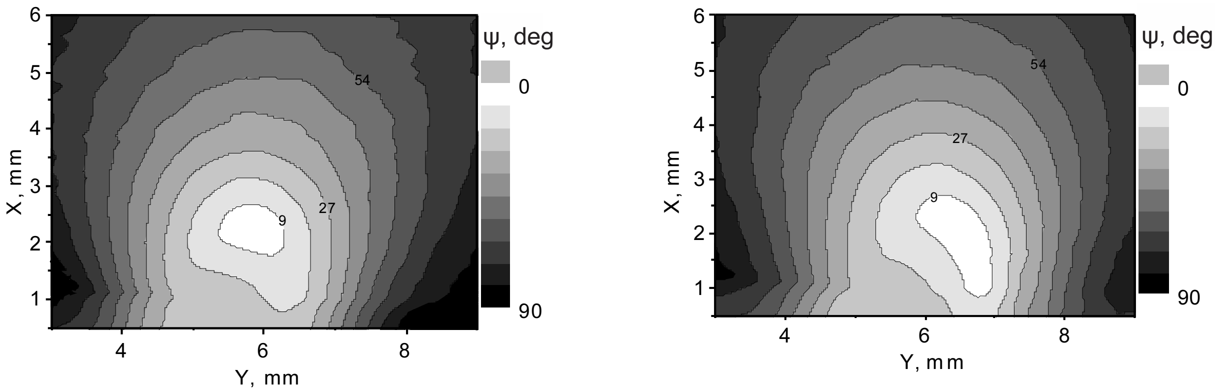


Fig. 10. Braille dot diameter change under different mechanical effect way length (abrasion time – 60 min) when Braille is formed using screen printing on different materials: 1 – on textile/cotton, 2 – on textile/polyester, 3 – on paper/uncoated, 4 – on paper/coated, 5 – on paperboard/Arktika, 6 – on paperboard/Mirabell, 7 – on Al foil, 8 – on polymer PP



a

b

Fig. 11. Distribution of mechanical stresses phase difference in matrix when embossed paperboard is Alaska GC-2 (a) and Arktika GC-1 (b) type

Forming Braille with embossing, the quality of elements during embossing process is affected by the contact of the stamp and material. After the test according to the polarimetric method given findings of the stresses distribution testing different type of paperboard specimens with Braille are shown in the digital images (Fig. 11). Obvious differences can be seen, because the tested paperboards have different structure. In this case the images are registered using circularly polarized light.

The following images (Fig. 11) show that the region with $\psi = 9$ (this is the area in which, according to the probe radiation of the circular polarization, phase difference caused by mechanical effect is $90^o - 9^o = 81^o$) for different paperboard types are different. As one can see the area obtained during testing in paperboard Alaska GC-2 is smaller, indicating that the stresses in the matrix and stamp originating when embossing paperboard Arktika GC-1. Thus according to the investigations findings, it can be stated that the durability of the stamps is bigger in case of lower stresses, i. e., forming Braille on Alaska GC-2 paperboard.

The application of this methodology is important for investigations of stamp (and matrix) stresses, because the information of stress distribution could give prognosis of stamp edition.

4. CONCLUSIONS

1. The performed mechanical effect test have showed that Braille dot height change, which was formed using screen printing on different materials, after 60 min of mechanical effect is different: on paperboard the height decreased by 45 %, paperboard Mirabell – 14 %, on textile cotton – 26 %, polyester 29 %, on textile – 27 %, on paper uncoated – 23 %, coated – 12 %, on polymer – 33 %, on Al foil – 26 %, from the initial Braille dot height.

2. It was determined that for the porous materials (textile, uncoated paper, recycled paperboard (Mirabell) the screen printing and plastisolic inks are most suitable because under mechanical effect the Braille dot remain less changed.

3. Braille formed on the cardboard Arktika using screen printing after mechanical impact time is difficult to read because the dot height is less than 0.17 mm.

4. Slightly increase of mechanical effect duration leads to increase of Braille dot diameter. This is caused by

mechanical compression of Braille dot, which was formed on different materials and using plastisolic inks which during compression spread.

5. Braille dots formed using plastisolic inks and affected by long-term mechanical effect are nondurable thus the Braille book printing using these inks is unadvisable.

6. Based on the obtained findings the suitable Braille forming type on different materials could be selected.

7. Stresses distribution was determined exposed in contact zone during Braille dots embossing. It was obtained that the stresses in the stamp are lesser when embossing Alaska GC-2 paperboard than Arktika GC-1. According to the test findings the stamps of enlarged circulation could be designed.

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