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Research of influencing factors on the change of geometric parameters of Braille elements on self-adhesive labels

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1. Introduction

The adaptation of blind people in their daily lives – it is an important socio-humanitarian and economic problem, the relevance of which requires the search for new technologies to improve the process of printing information in Braille on labels and packaging used by blind people. Therefore, in this document main attention is focused on the study of the influence of technological factors and regime of digital printing to form Braille relief-dot elements.

The main purpose of Braille – is creating a comfortable environment for people with weak or completely absent vision in communication in commerce, social networks and more. According to international requirements (Directive of the European Parliament and of the Council 2004/27/ES from 31.03.2004) in the pharmaceutical industry for drugs along with the usual text is mandatory description of the product in Braille [1, 2]. Obviously, labeling in Braille in the future will be mandatory for manufacturers of food and chemical industries.

The Braille can be formed on self-adhesive labels which are widely used for various purposes and types packages. Self-adhesive label consists of a surface coating paper or synthetic base layer of adhesive and substrate (Fig. 1). The choice of material and technology of causing the image on the stick depends on the destination and its area of use [3].

The high-quality tactile images for the blind people can be made with regard to the relevant assessment criteria in Braille, in particular: the relief height, profile characteristic element, adhesion of relief items to the base material, abrasion resistance and peel under the fingers, durability, and tactile sensations [4].

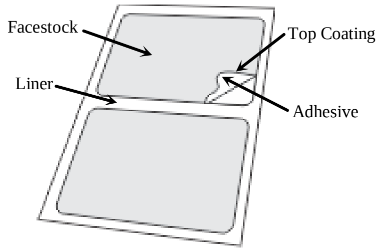


Fig. 1 Key components of self-adhesive label

The relief images designed for "scanning" by fingers of blind persons can be made by using different technological variants. It should be taking into account length runs, the mechanization of manufacturing operations, production costs, the time required to print one copy, when choosing the technology of creating relief-dot elements.

Analytical review of scientific publications and patent searches conducted technical solutions [5-9] allowed us to develop a detailed classification of methods of applying image labeling for the blind people. For printed relief images are used:

Contact methods:

- stamping on cardboard (corrugated board), special types of paper and films by stamps;
- screen printing on special paper with thick layers of paint that does not flow, or composition, creating relief on the plane due to thermal imprint;

Non-contact methods (digital printing):

- ink-jet printing with special varnish composition;
- methods of getting relief images using polymer and other thermo chemical materials on laser printers.

The choice of a reproduction technology depends on the scope, purpose, categories of users and available resources. However, experience shows that the need for significant investment is the first and perhaps the most important problem in implementing inscriptions in Braille.

The analysis shows that today's printing market is dominated by two methods of reproduction of information for blind people. The first is the formation of relief items by stamping and is more common in European countries through a number of advantages with regard to the cost of the order and speed of its implementation. But despite its popularity, this technology has significant disadvantages, namely: restrictions in height of Braille relief-dot elements, not always satisfactory requirements for mechanical strength, which leads to a decrease bump in the operation of such texts by blind people. Widespread technology of reproduction of information for blind people is a screen printing method, which can be implemented on a variety of materials – paper, cardboard, film and more. Moreover, the use of this method provides significant resistance relief items to mechanical influence during transport and reading by blind people.

Becoming popular digital printing thus relief-dot images can be implemented on a self-adhesive label. One of the most innovative and flexible solution is digital ink-jet printing when the Braille dots are printed using high viscosity transparent UV dried varnish on various materials. Quality of items Braille printed on self-adhesive label depends on technological (physical and mechanical properties of the substrate and varnish) and operating conditions (temperature and pressure of varnish, substrate feed rate) factors that require detailed studies for getting quality tactile images. Printing Braille with ink-jet, varnish viscosity and printing material surface stresses have effect to Braille dot size [10-12].

The Braille printing on self-adhesive labels using digital print still lack studies. Thus the aim of this paper is to determine optimal values of printing speed and varnish temperature and the dot peel force when Braille is formed under different technological regimes on various materials.

2. Experiment equipment and method

The objects of research were images in Braille, created by digital ink-jet printing machine Braillemaker One Convertec with special transparent varnish Braille Maker Varnish 1.0 A. (see Table 1). Transparent and clear Braille dots can be printed on various materials (Top-coated PE, PA, PET, Alu., Paper, Carton, Silicone free varnished substrates) using this printing machine. The Braille dots of 1.40-2.00×10^{-3} m diameter and 0.20-0.40 ×10^{-3} m height Braille dots This printing machine ensures the accuracy of printing of Braille elements (tolerance with in the Braille dots ± 0,10 mm, tolerance between blocks ± 0,15 mm) [13, 14].

Table 1

Physical and chemical properties of Braille Maker Varnish 1.0 A

General information	
Aggregate state	liquid
Colour	yellow
Odor	characteristic
Specifications	
Freezing	Not Specified
Boiling point / range	>100°C
Ignition temperature	101°C
Danger of explosion	It is not explosive
Density at 20°C	1.08 g/cm^3
Stickiness at 23°C	600-800 MPa·s
Solubility in water	insoluble or sparingly soluble
Stability	Stable under normal conditions

The samples were printed with variable printing modes (temperature (from 51 to 59°C) and pressure of varnish (from 2.0×10^5 to 3.0×10^5 Pa), substrate feed rate (from 0.25 to 0.75 m/s) on 2 different self-adhesive labels (substrates), a width of 76.00×10^{-3} m: a) paper PrimeCoat MC S2000 (a white, one side machine coated, wood free printing paper with semi-gloss appearance with basis weight 80 g/m^2); b) polyethylene film FASSON PE85 WHITE S692N-BG40WH (a blown, corona-treated white polyethylene film with medium gloss appearance with basis weight 82 g/m^2).

For estimation of geometric parameters, obtained relief-dot elements when changing technological conditions of deposition was used metering devices FlexoCam (Fig. 2) [15] and a digital microscope IntelPlay QX3 [16].

The FlexoCAM solution consists of the 24-bit RGB camera with a resolution of 640×480 pixels which assistance takes a 3D view of dot structures and halftone dot readings. Detailed color images are viewed on a PC screen with the device linking directly via a USB interface. The FlexoCAM is equipped with a coaxial light and a three-array radial light source consisting of 16 LEDs which can be switched on or off individually or in groups to achieve the optimum illumination of the area to be measured.

Fig. 2 Means of measuring geometrical size of Braille: device FlexoCam, where *1* - mobile head with CCD-camera and moving, with variable lens with coaxial LED lighting, *2* - mobile foot with side LED lighting, *3* - the scope of test sample

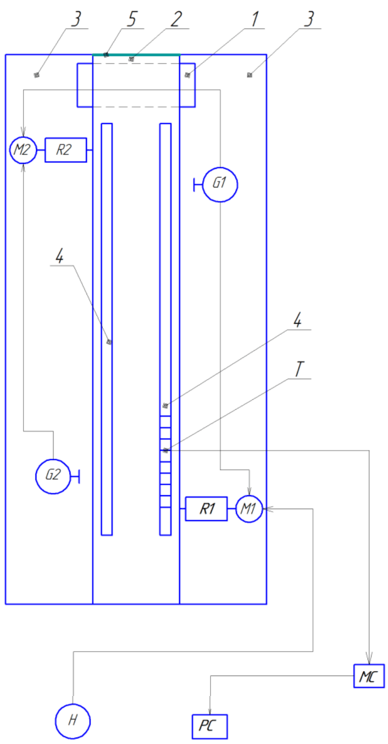


Fig. 3 Principal scheme of device for determining the resistance to peel of Braille elements, where *1* - test sample, *2* - movable plate, *3* - stationary surface, *4* - gear rack, *5* - scraper, H - switch button, PC - personal computer, MC - microcontroller, M1 and M2 - motors, R1 and R2 - reducers, G1 and G2 - switches

To determine the resistance to peel of Braille characters using a specially designed device (Fig. 3) that works as follows: the moving plate with fixed scraper set in motion by the mechanism of tension, which includes motors, reducers and switches; scraper element moves on the surface of the device with prior fixed test sample; in the moment of contact of scraper with the Braille element it is peel from the base of surface (self-adhesive paper and film); the value of the pulling force is fixing and transmitting by strain to personal computer.

3. Results and discussion

The analysis of the photomicrographs and topographies of Braille dots surfaces (Fig. 4) has allowed to build graphical dependence (Fig. 5-6), which shows the relationship between geometric parameters (diameter and height) relief-dot elements and technological modes of printing:

- an increase the substrate feed rate from 0.25 to 0.75 m/s leads to reduce dot's diameter from 1.62×10^{-3} m to 1.54×10^{-3} m (on paper base), from 1.64×10^{-3} m to 1.56×10^{-3} m (on polyethylene film) and to an increase its height from 0.19×10^{-3} m to 0.23×10^{-3} m (on paper base), from 0.20 to 0.23×10^{-3} m (on polyethylene film) (t_{opt} = 59°C, $P_{opt} = 2.5 \times 10^5$ Pa);
- an increase varnish temperature from 51 to 59°C accompanied by a decrease of its viscosity, causing a drop spreading and increasing the dot's diameter from 1.56 to 1.58×10^{-3} m on paper base and from 1.58 to 1.60×10^{-3} m on polyethylene film and to an increase its height from 0.19 to 0.22×10^{-3} m (on paper base), from 0.20 to 0.23×10^{3} m (on polyethylene film) (V_{opt} = 0.58 m/s, $P_{opt} = 2.5 \times 10^5$ Pa);
- the increase of pressure in the nozzle of varnish digital device from 2.0 to 2.5×10^5 Pa leads to reduce of Braille dots diameter from 1.6 to 1.58×10^{-3} m (on paper base), from 1.62 to 1.60×10^{-3} m (on polyethylene film) and to an increase its height from 0.18 to 0.22×10^{-3} m (on paper base), from 0.19 to 0.23×10^{-3} m (on polyethylene film) (t_{opt} = 59°C, V_{opt} = 0.58 m/s). Further increasing the pressure to 3.0×10^5 Pa does not change geometrical parameters of Braille point.

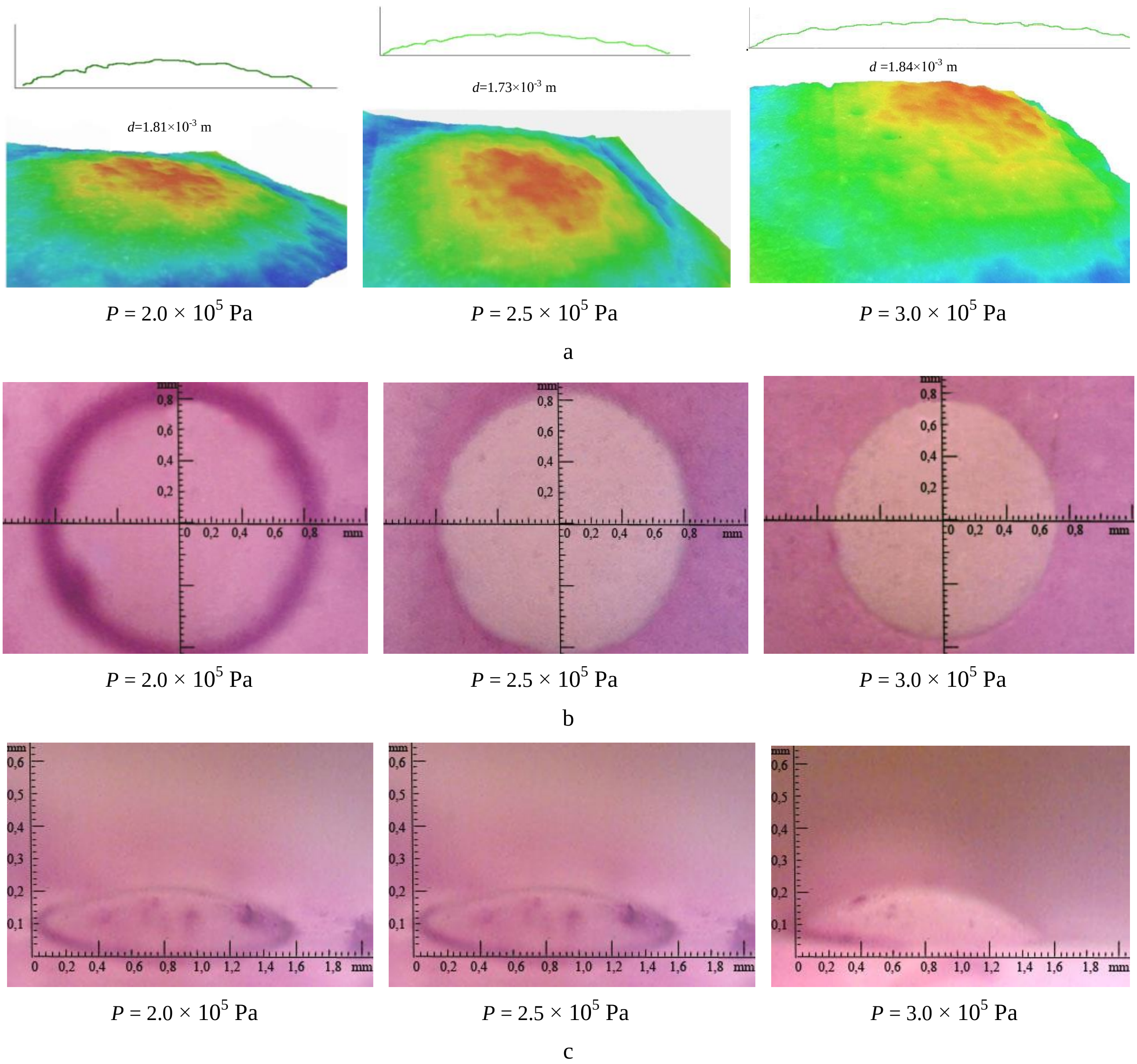
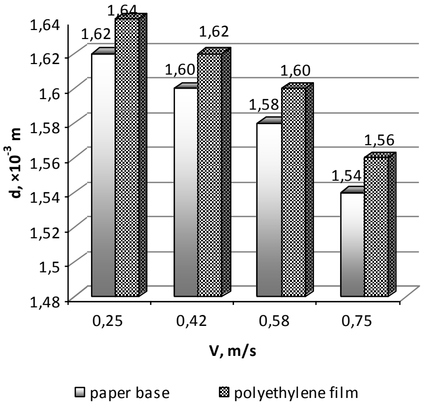
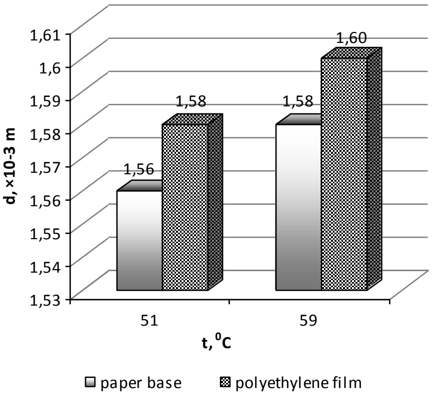


Fig. 4 Image of Braille dot formed by digital printing at t = 59°C, V = 0.58 m/s on paper base, when $P = 2.0 \times 10^5$ Pa, $P = 2.5 \times 10^5$ Pa, $P = 3.0 \times 10^5$ Pa: a - Braille's dot surface topography and profilogram; b - top view; c - side view (magnification 60 times)



a



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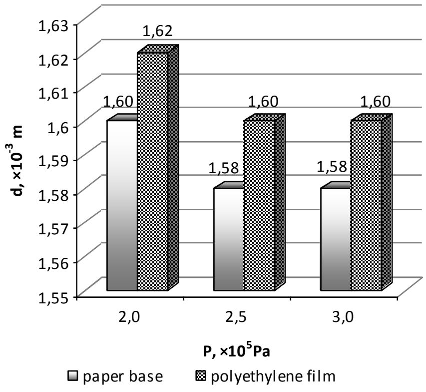
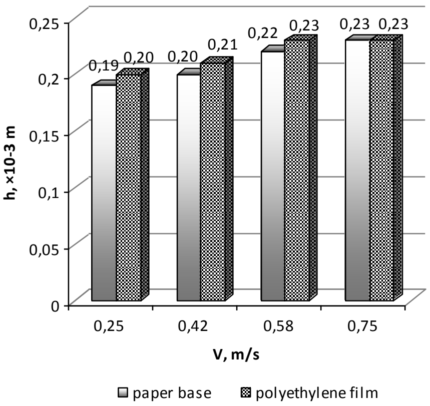


c

Fig. 5 Dependence of the Braille dot's diameter *d* from printing technological regimes: a - from substrate feed rate *V*, when varnish temperature $t = 59°C$, pressure in the nozzle $P = 2.5 \times 10^5$ Pa; b - from varnish temperature *t*, when substrate feed rate $V = 0.58$ m/s, pressure in the nozzle $P = 2.5 \times 10^5$ Pa; c - from pressure in the nozzle *P*, when varnish temperature $t = 59°C$, substrate feed rate $V = 0.58$ m/s



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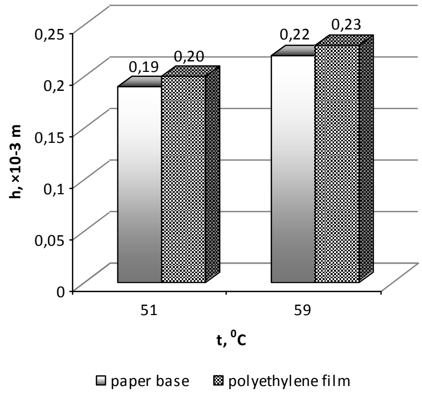

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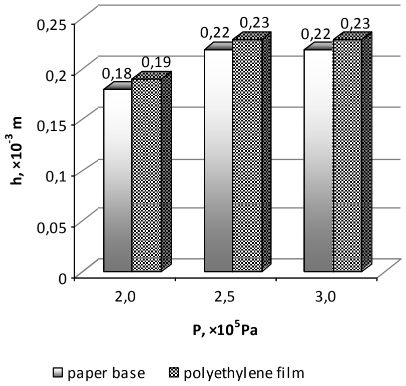


c

Fig. 6 Dependence of the Braille dot's height *h* from printing technological regimes: a - from substrate feed rate *V*, when varnish temperature $t = 59°C$, pressure in the nozzle $P = 2.5 \times 10^5$ Pa; b - from varnish temperature *t*, when substrate feed rate $V = 0.58$ m/s, pressure in the nozzle $P = 2.5 \times 10^5$ Pa; c - from pressure in the nozzle *P*, when varnish temperature $t = 59°C$, substrate feed rate $V = 0.58$ m/s

Table 2

Optimal Braille geometrical parameter values and the printing technological regimes

Technological regimes		Paper		Polyethylene film	
		Dots diameter, *d*, $\times10^{-3}$ m	Dots height, *h*, $\times10^{-3}$ m	Dots diameter, *d*, $\times10^{-3}$ m	Dots height, *h*, $\times10^{-3}$ m
Substrate feed rate *V*, m/s	0.58	1.58	0.22	1.60	0.23
Pressure in the nozzle *P*, Pa	2.5×10^5				
Varnish temperature *t*,°C	59				

Table 2 presents geometrical parameters of Braille obtained under various technological regimes which are easy read by the blinds. Thus we believe that are optimal. The optimal geometrical parameters were determined carrying out mathematical-statistical analysis of obtained data. It is determined that the findings of the experimental researches meet the normal distribution law. The research data meet the equation of this law:

$$y = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x_i - x)^2}{2\sigma^2}}, \quad (1)$$

where σ is root-mean-square deviation; x_i is the value of separate finding; x is center of distribution (general average).

The analysis of experimental results, the estimated coefficient of variation:

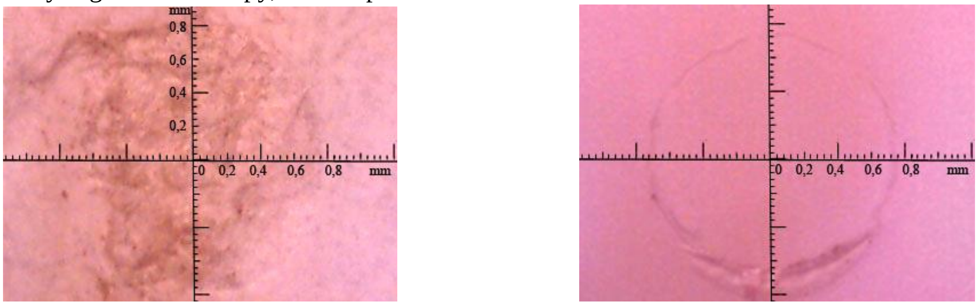
$$v = \frac{s}{\bar{x}} 100, \% \quad (2)$$

where: s is standard deviation, $\bar{x}$ is the arithmetic average.

The coefficient of variation is 5% thus it can be stated that the scattering of experimental findings is low.

As a result of investigation, the optimal values of geometrical sizes of Braille dot are detected with the following technological conditions: the substrate feed rate $V = 0.58$ m/s, the varnish temperature $t = 59°C$, the pressure in the nozzle $P = 2.5 \times 10^5$ Pa (Table 2). The results of experimental studies have shown the influence of the material base for resistance to peel Braille dots (the resistance to peel of dots on film base is 35 N, on paper base - 32 N).

According to the researches of stability of images (Fig. 7), recorded by digital microscopy, on samples with paper base, the peel of the dots comes from the destruction of the structure of the surface layers of self-adhesive paper and the peel of relief elements deposited on the film base comes without damage to its structure (difference in the peel strength is 3 N) (Table 3).



a b

Fig. 7 Photomicrographs of Braille dots after peel: a - paper base, b - film base

Table 3

Braille dots resistance to peel at the optimal printing technological regimes

Technological regimes		Peel strength, P_{st}, N	
		Paper	Polyethylene film
Substrate feed rate V, m/s	0.58	32	35
Pressure in the nozzle P, Pa	2.5×10^5		
Varnish temperature t, °C	59		

4. Conclusions

1. Conducted experimental researches of relief-dot elements, digitally printed on self-adhesive label, allowed establishing the value of their adhesion to the substrate and the dependence of geometric parameters of Braille characters from technological and regime factors of the printing process.

2. Investigated, that speed increase in the formation of relief-dot image by digital printing leads to decrease in diameter and increase in the height of the dot.

3. Braille parameters best read by the blinds were printed under following regimes: substrate feed rate $V = 0.58$ m/s, the varnish temperature $t = 59$°C, the pressure in the nozzle $P = 2.5 \times 10^5$ Pa.

4. Optimal geometrical parameters of Braille printed on paper-based self-adhesive labels are as follows: $d = 1.58 \times 10^{-3}$ m, $h = 0.22 \times 10^{-3}$ m, and polyethylene-based: $d = 1.60 \times 10^{-3}$ m, $h = 0.23 \times 10^{-3}$ m.

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LIPNIOSE ETIKETĖSE SUFORMUOTO BRAILIO RAŠTO GEOMETRINIŲ PARAMETRŲ DYDŽIUS ĮTAKOJANČIŲ FAKTORIŲ TYRIMAI

R e z i u m ė

Straipsnyje pateikti reljefinių Brailio rašto elementų, atspausdintų skaitmenine spauda ant lipnių etikečių, tyrimų rezultatai. Nustatyta technologinių ir režiminių faktorių įtaka geometriniams Brailio rašto simbolių parametrams. Nustatyta, kad didinant skaitmeninio spausdinimo greitį nuo 0.25 iki 0.75 m/s, Brailio rašto taškų skersmuo mažėja, o aukštis didėja. Lako temperatūros padidėjimas mažina jo klampumą, kas iššaukia Brailio rašto taško skersmens padidėjimą. Atlikus tyrimo rezultatų matematinę-statistinę analizę buvo nustatyti optimalūs spausdinimo režimai (spausdinamosios medžiagos judėjimo greitis – 0.58 m/s; lako temperatūra – 59°C, spausdinimo galvutės slėgis – 2.5×10^5 Pa), kurie užtikrina norminius Brailio rašto geometrinius parametrus (Brailio rašto taško skersmuo – $1.60 \pm 0.10 \times 10^{-3}$ m, Brailio rašto taško aukštis $0.16–0.20 \times 10^{-3}$ m).

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RESEARCH OF INFLUENCING FACTORS ON THE CHANGE OF GEOMETRIC PARAMETERS OF BRAILLE ELEMENTS ON SELF-ADHESIVE LABELS

S u m m a r y

Test results of relief Braille elements printed on adhesive labels using digital printing are given. The effect of technological and mode factors to Braille symbol parameters was determined. It was shown that increasing digital printing speed from 0.25 up to 0.75 m/s, Braille dot diameter decreases and the height increases. The rise of varnish temperature reduces its viscosity, resulting in higher Braille dot diameter. Optimal printing modes were determined according to statistical analysis of experimental tests results (feeding speed of printing material – 0.58 m/s; varnish temperature – 59°C; the pressure in printing head – 2.5×10^5 Pa) which enable to form normative Braille dot parameters (Braill dot diameter – $1.60 \pm 0.10 \times 10^{-3}$ m, Braille dot height $0.16–0.20 \times 10^{-3}$ m).

Keywords: Braille, Braille dot, Braille on self-adhesive labels, digital ink-jet printing.

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