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Analytical design of printing elements of Braille device

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This paper presents a structural scheme of the model to generate profiles of needle printing elements of Braille printer to publish books for the blind. The examples of computer simulation of the profile of needle printing elements for paper and cardboard have been presented.

To ensure social, cultural and information needs of blind people it is important to improve the process of manufacturing printed materials for this group of people. The problem of inclusive education and the production of educational, artistic and other publications in Braille is always relevant as the rehabilitation, correctional and special pedagogy for people with disabilities has increasing scientific, practical and state interest [1, 2].

The traditional and most common technology of manufacturing printed products for the blind is congreve stamping. Originally it was used on flat-bed and crucible machines. Such paper or cardboard was put between the stamp and the matrix and convex relief elements of Braille text were formed under the pressure.

Now to get relief images we widely use Braille printers that can print out texts in any text editor, creating Braille documents that are ready for use immediately after printing. In modern Braille printers the matrix is in the form of three or four matrix lines, allowing you to print the characters instantly. The moving head, shifting on the matrix ruler, embosses convex relief elements or characters on the paper with a needle or needles. The homogeneity of relief elements and characters on the print is largely dependent on the precision of manufacturing and printing elements shape that defines the character recognition by touch, convenience and reading pace of Braille text. When the printing speed rises, the wear of matrices increases and there are significant noise levels of up to 68 dB. To reduce the wear of printing elements and noise it is necessary to improve the accuracy of their manufacturing and make the surface smoother.

From the above mentioned facts, the task is to improve the accuracy of Braille printing elements, which is solved by analytical design. First, we consider the problem of analytical design of printing head needles which lies in the mathematical description of the needle shape as a printing element, the development of a simulator to determine the digital data needed to compile the program of the program control system of the device on which printing elements will be produced.

To solve this problem we use mathematical models of Braille character. For this, we modify the function of the profile of Braille character element (1) by "cropping" of the function below, and its shifting to the original point [3, 4].

$$Y(x) = F(x, d, h, a) \tag{1}$$

where *F(x, d, h, a)* is some non-linear function, you want to find, x is the spatial variable (coordinate), a is the character width – the horizontal distance between the centers of the images of two elements of one character placed in vertical adjacent columns, d is the base width (dot diameter), h is the dot height.

Then we receive the function (2) of the profile of the needle printing element of Braille printer head:

$$Y_2 = F(x + x_0, d_2, h_2) \tag{2}$$

where x is the spatial variable (coordinate), x_0 is the shifting value, d_2 is the diameter of printing element base, h_2 is the nominal height of the element.

The function of the profile of the needle printing element will be like (3).

$$Y(x) = \left[1 - \frac{1}{\sqrt{1 + v^r u^r}}\right] h \tag{3}$$

where h is the nominal height of the character element, v is the spatial constant of the element (spatial frequency), which sets the element shape, r is the exponent, the integer, u is the spatial variable.

The spatial variable u is set by the expression:

$$u = \begin{cases} Ax & \text{for } 0 \le x \le \frac{d_2}{2} \\ A\left(\frac{d_2}{2} - x\right) & \text{for } \frac{d_2}{2} \le x \le d_2 \end{cases} \tag{4}$$

Based on the profile function and expression of the spatial function (4) we have built the structural scheme of the model to generate profiles of the needle printing elements of Braille printer, which is shown in Fig. 1.

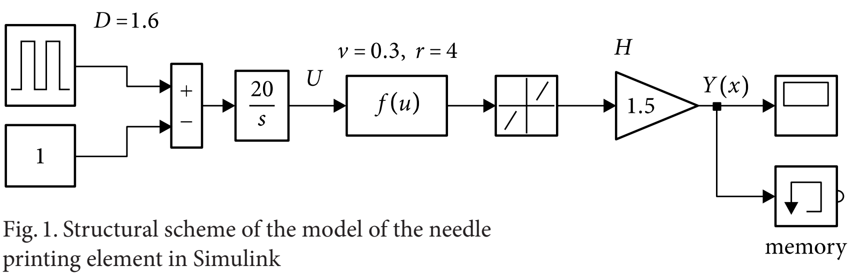

Fig. 1. Structural scheme of the model of the needle printing element in Simulink

Initially the profile of the printing element is formed here, at the end the lower part of the profile is cropped with the help of the block Dead Zone. The diameter of the printing element base is specified in the dialog window of the block

Puls Generator. The block Memory is used to store the digital data of the function of the profile of the needle printing element.

Based on the above we have developed the simulator of the profiles of the needle printing elements according to the structural scheme of the model in Fig. 1 and taking into consideration the expressions (2) and (4), through which the analytical design has been done. The simulator allows generating three different profiles of the needle printing elements at the same time, to visualize and store digital data of the profile.

We have done a computer simulation of the profile of the needle printing element for cardboard as an example. We set the base diameter $d = 1.4$ mm, the spatial constant $v = 0.3$, the exponent $r = 4$. The results of the simulation are presented in Fig. 2 for three element heights $h = 1.5, 1.2, 1$ mm.

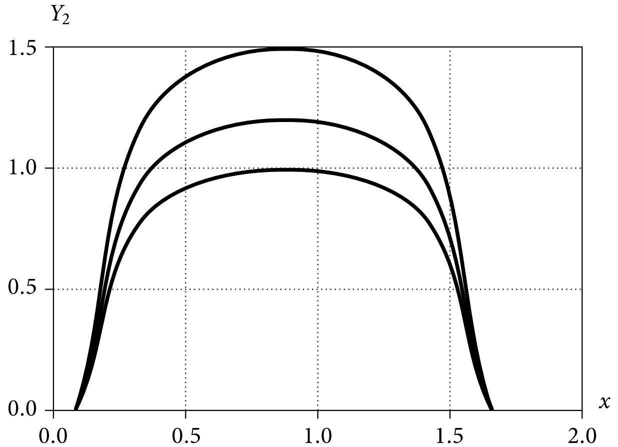

Fig. 2. The graphs of the profiles of the needle printing elements for the cardboard

The profile of the needle printing elements for the paper is presented in Fig. 3 ($v = 0.4$, $r = 6$).

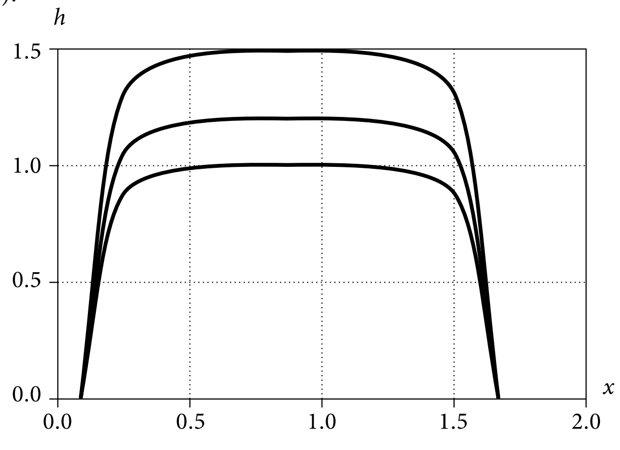

Fig 3. The graphs of the profiles of the needle printing elements for the paper

Now we consider the problem of analytical design of the matrix printing element that needs to be structurally convenient to design a matrix line. To describe it we use the model of the relief element. We make the function of the profile of the matrix functional elements:

$$Y_M(x) = F(x, d_M, h_M, b) \tag{5}$$

where d_M is the diameter of the matrix base, h_M is the nominal depth of the matrix, b is the width of the base of the matrix printing element.

The function of the profile which describes the shape of its vertical axial section is

$$Y_M(x) = \left[1 - \frac{1}{\sqrt{1 + \nu^r u^r}}\right](-h_M) \tag{6}$$

The spatial variable is set by the expression:

$$u = \begin{cases} 0 & \text{for } 0 \le x \le \frac{b-d_M}{2} \\ Ax & \text{for } \frac{b-d_M}{2} \le x \le \frac{b}{2} \\ A\left(\frac{b}{2} - x\right) & \text{for } \frac{b}{2} \le x \le \frac{b+d_M}{2} \\ 0 & \text{for } \frac{b+d_M}{2} \le x \le b \end{cases} \tag{7}$$

Based on the function of the profile (5) and the expression of spatial variable (7) we have built the structural scheme of the model to generate profiles of the matrix printing element in Simulink, which is shown in Figure 4.

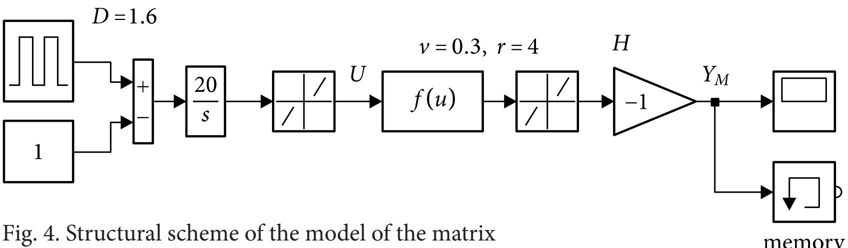

Fig. 4. Structural scheme of the model of the matrix printing element in Simulink

We should note that the first non-linear block Dead Zone crops the spatial variable according to the given diameter of the matrix base and the second block crops its rounded part. The Memory block stores the digital data of the matrix profile. Based on the above we have developed the simulator according to the structural scheme of the model in Fig. 4 and the expressions (6) and (7) through which the analytic design of the matrix printing element has been done.

We have processed the parameters of the model adjustment: the spatial constant ν = 0.25-4, the exponent r = 4-6 for the matrix depth h_M = 1.5, 1.2, 1.0 mm. We have adjusted the simulator to the following parameters: ν = 0.3, r = 4. Using the simulator we have done the analytical design of the matrix printing elements. The example of the design results in the form of structures of the matrix printing element with the width $b = 1.5$ mm, the diameter of the matrix base $d_M = 1.6$ mm and the depth 1mm is presented in Fig. 5 [4, 5].

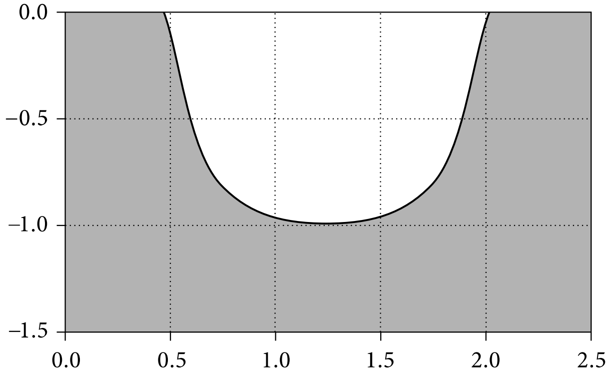

Fig 5. The example of the design of the matrix printing element

To quantify the desired shape of the matrix printing elements, to compare their shape and make the optimal selection, we can use the integral criteria of the evaluation of Braille character parameters. The simulator allows the parallel design of three different profiles of the matrix printing elements set by the geometrical parameters of the desired shapes and calculates the relative integral evaluation criteria, which is convenient for practical applications and comparative analysis of the optimal shape selection that facilitates the design.

References

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Streszczenie

Analiza projektu elementów drukujących urządzenia tłoczącego znaki alfabetu Braille'a

Przygotowanie materiałów drukowanych dla osób niedowidzących i niewidomych wymaga użycia alfabetu Braille'a, który tradycyjnie powstaje w wyniku tłoczenia. Rozpowszechnienie cyfrowych metod przygotowania do druku oraz drukowania sprawiło, że powstały także technologie tłoczenia symboli alfabetu

Braille'a za pomocą urządzeń przypominających drukarki igłowe. Wymagania czytelności oraz niezawodności zmuszają do odpowiedniego zaprojektowania kształtu igły tłocznika oraz dopasowania jej charakterystyki do rodzaju użytego podłoża. W artykule opisano analityczną metodę projektowania kształtu tłocznika w oparciu o model matematyczny elementu alfabetu Braille'a przygotowany do wykorzystania w programie Matlab Simulink oraz zaprezentowano wyniki obliczeń dla różnych podłoży i parametrów tłoczenia.