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Development of polygraphic program-controlled hardware system for applying high-density coding on surface of products made from varied materials

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Abstract. A program-controlled hardware system that does not have domestic or foreign analogues was developed and tested for printing high-density codes and their identification on the surface of products from varied materials. The input information encoding, using a random variable generator, which excludes the possibility of reading the recorded text without knowing the individual coding key, provides the uniqueness of the applied high-density code. The proposed marking technology ensures the placement of a large amount of information on a small area and the successful recognition of the high-density code by an original reading device with the original decryption software. The performed scanning device has a higher resolution than the existing standard barcode scanners.

1. Introduction

The present methods of marking metal products, in general, are based on the printing marking symbols to intermediate carriers - labels, tags, packaging. Recently developed methods of direct part marking (the method of extruding text, writing with an electric spark pencil, etc.) are not widely used because of the their forgery possibility and due to the inability to introduce a large amount of information. With the usage of the high-density codesprinted by lasers directly on the finished products surface, a much greater counterfeit products protection is provided [1]. The application of two-dimensional high-density codes directly to the products also allows one to solve one more important problem: to place and carry the necessary information on the product itself with its production and operation conditions characteristics [2, 3] (figure 1).

Data-Matrix QR-code PDF-417 High-density code, x4

Figure 1. Two-dimensional matrix and high-density codes printed by laser on the plate Ti-Grade 2.

However and up to now a fairly wide application of direct part marking by means of lasers has not been received. This is due to the fact that the laser marking technology of the final products even with using standart matrix codes or barcodes is quite complex, requiring high qualification of engineering personnel capable of applying "readable" barcodes to products [4, 5]. When it is nesseseary to enter a sufficiently large amount of information (more than 1000 characters) in the stanard code, the dimensions of the bar or two-dimensional matrix codes themselves (table 1) noticeably increase that does not allow them to be used for a small size products.

Table 1. Comparing the sizes of different code types.

Code type	The actual code size		
	100 symbols (1 line)	1000 symbols (2/3 of page)	10000 symbols (6 ½ of page)
High-density code	2,41×2,41 mm	4,75×4,75 mm	14,41×14,41 mm
QR-code	11,00×11,00 mm	32,00×32,15 mm	-
PDF 417	15,90×13,50 mm	33,75×33,60 mm	-
Data matrix	19,05×19,05 mm	55,05×55,05 mm	159,08×159,08 mm

Based on the deficiency analysis of the existing bar-coding technologies for finished products, a polygraphic program-controlled hardware system was developed [6]. It actualizes two technological processes: the high density codes printing and an identification of the encrypted information. The applied high-density codes have an ultra-high recording density of bit-coded information – information field – printed directly on the product surfaces made from metal, inorganic and polymeric materials. The proposed polygraphic system includes a precision pulsed laser, a control module and a scanning devicee that reads and decodes stored information in a high-density code [7].

2. Coding program interface

The control module allows the required information to transfer in the form of a coded text and / or a color image (for example, an enterprise logo) from a computer using the original program to laser software that generates a color image and / or a corresponding information field in the form of a high-density code on a product surface [6, 8].

When downloading a text file for encoding, the encoding program offers to select (figure 2) the product material (steel 08X13) and then automatically selectsthe name of the laser complex (DMark-06), the technological parameters of the laser marking process (the lamp current is 10 A, the diameter - 66.12 μm, dpi - 384.14, laser radiation frequency - 300 Hz, delay - 100 ms). Ather selecting the mentioned parameters, the program forms a graphic file which creates symbol of a high-density code maximally close to a square shape (size 16,389 × 15,935mm).

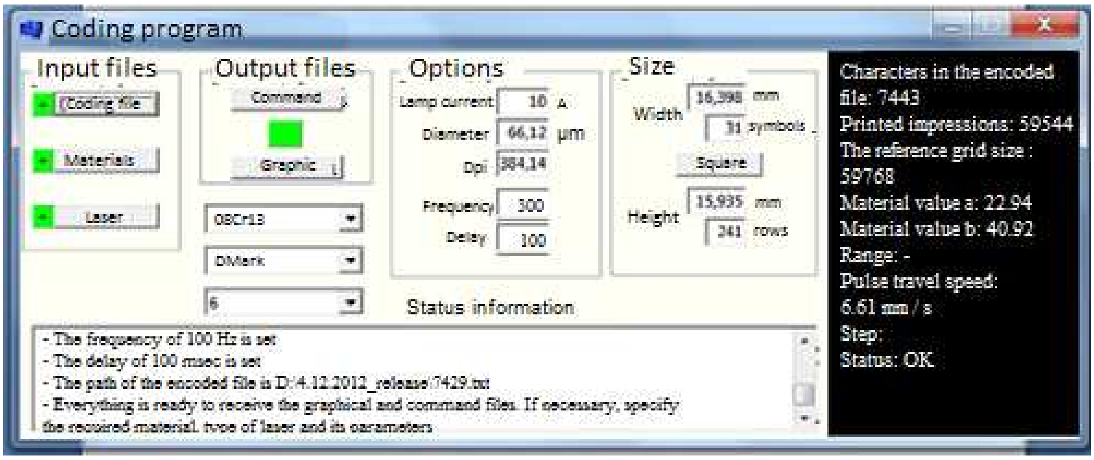


Figure 2. Selecting the material of the product and the laser marking parameters.

Compared with existing analogs, the high-density code obtained by printing with the polygraphic program-controlled hardware system contains a much larger volume of textual information on a small surface area of the product, so as a precision pulsed laser allows one to apply high density of information recording in the marking symbol due to the coding compression (table 1).

If it is necessary that the system allows printing the logo of the enterprise with high accuracy, including multi-color [2]. The data entered in the high-density code field will remain unchanged during the entire lifetime of the product, and it will be possible in a case of emergency destruction to get an objective expert opinion on the cause of the product breakage using an information from the mark [9].

3. Scanning device

An integral part of the polygraphic program-controlled hardware system is an original scanning device that was designed to recognize coded symbols and transfer their images to the control module for decoding the input recorded information by means of the special program. The general block diagram of the scanning device system is based on NI technology with the possibility of using digital camera modules with high resolution sensors as registers (figure 3) [10].

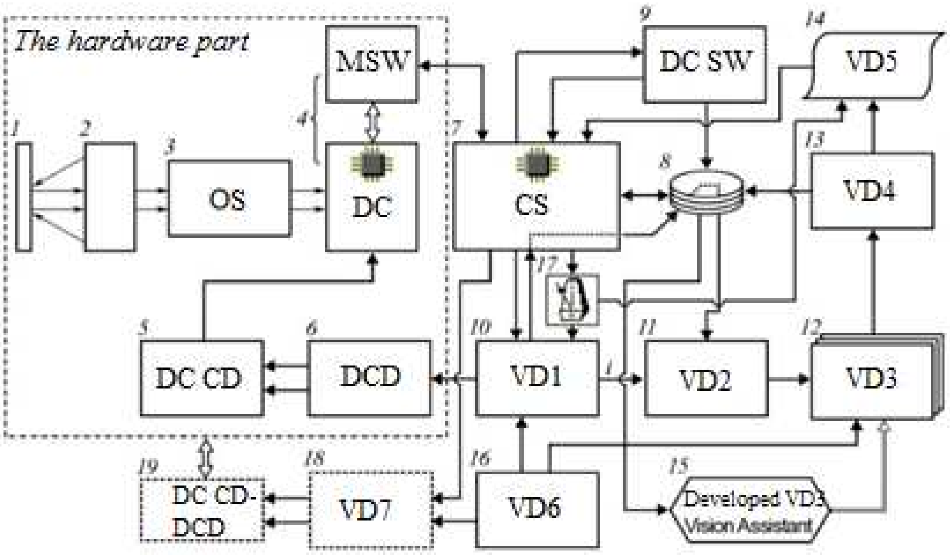


Figure 3. The general block diagram of the scanning devise system based on NI technology.

The block diagram of the scanning devise system contains a hardware component that includes: the object of control - 1, the lighting device - 2, the optical system - 3, the digital camera 4. The system also contains a control device - 5, a data collection device - 6, a computer system - 7, external storage - 8. The digital camera must have a wired (high-speed USB) or wireless (Wi-Fi) interface with a computer, a remote control interface (with a contact type N3 for the digital camera), a wireless controller (LC -5) or remote controller RC-6. Canon's digital cameras (EOS 6D) are fully in line with these requirements.

The functional modules implement the software: digital camera software - 9, a virtual device for the digital camera control - 10, the current image obtaining module - 11, the image processing and analysis module -12, the measurement module - 13, the result formation and display module - 14. Development of the image processing script, analysis and measurement and the creating fragments are in the application NI Vision Assistant - 15. The atomization module 16 provides obtaining images at specified time intervals, displays them on the screen and selects the image-processing algorithm.

Figure 4 shows the layout of the scanning device, realizing the proposed structural block diagram of the process control of registration and of high-density code recognition (figure 3). The optical circuit of the scanning device contains an annular illuminator - 4 (KONIG), a macro lens - 5 (AF MICRO NIKKOR 60 mm 1: 2.8D with an EOS adapter), a digital camera - 6 (EOS 50D), a reiter - 7.

4. Results and discussion

The scanning (reading) device can register the high-density codes printed by the laser marker to various metal surfaces, determine the lighting conditions, investigate the parameter effects inside the camera settings, investigate the image-processing algorithms in order to recognize and determine the coordinates of the laser prints of the code.

Figure 5 demonstrates the efficiency of using in an optical system a ring illuminator with a circular aperture of an objective. With a normal illuminator (diffuse light), the prints structure crater elements are visible (figure 5, a), while using the principle of an angular filtration (figure5, b), each imprint is registered as a dark field. In addition, there is an effective filtration of defects in the metal surface (scratches). Figure 6 presents a simplified script of processing and recognizing the code in the NI Vision Assistant application that displays the effectiveness of determining the laser prints coordinates of the image code structure [11].

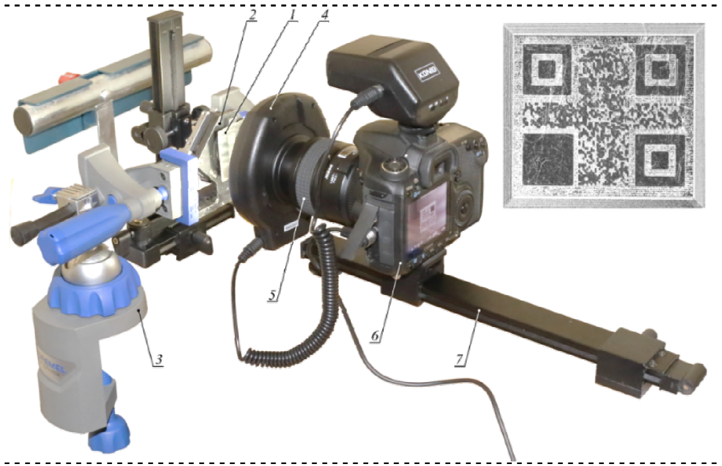
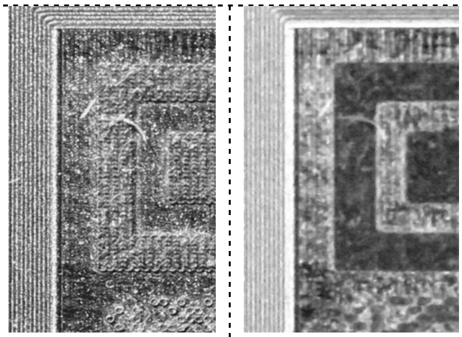


Figure 4. The reading device: 1 - the object of investigation, 2 - the alignment unit, 3 - the sample holder, 4 - the ring illuminator, 5 - the macro lens, 6 - the digital camera, 7 - the rider.



a) b)

Figure 5. Fragment of the high-density code image: a) underanormal lighting, b) a ring illuminator, an angular filtration.

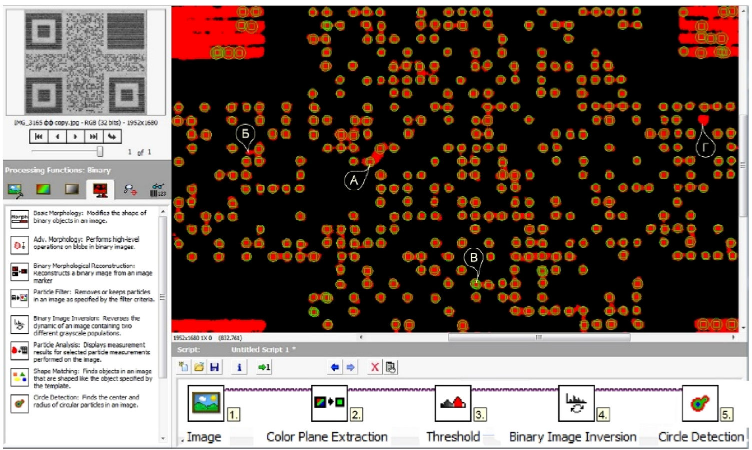


Figure 6. The result of high-density code image recognition in NI Vision Assistant.

The digital image of the high-density code is loaded into a special decoding program. The general view of the decoding program is shown in figure 7. The working field of the program presents the area where the code image is located. There is animage zoom select bar on the right part of the window. The range is from 100 to 1000% of the initial linear dimensions of the original image. When image zoom is selected with the scale of 1000%, the code'simage fills the entire working area of the program window. An auxiliary grid might be selected by clicking the "restore selection" button. Figure 8 shows the decoding program window with the restored auxiliary grid.

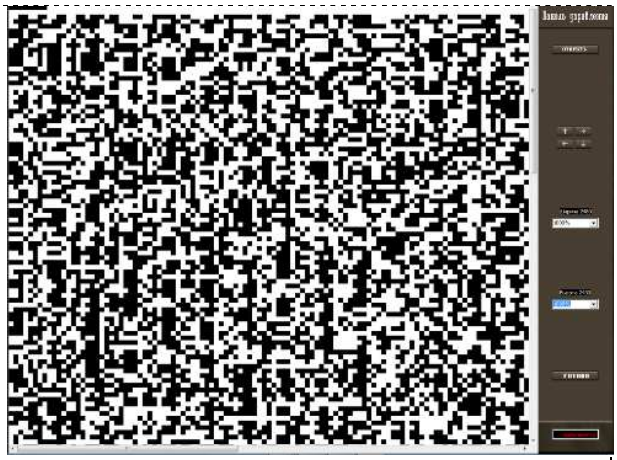


Figure 7. Picture of high-density code in the scale of 1000%/

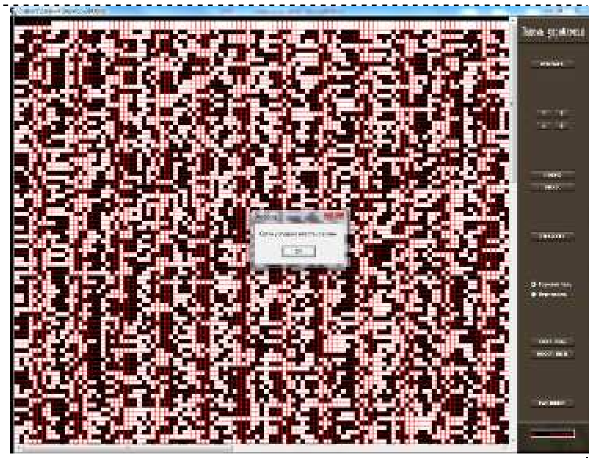


Figure 8. Decoding program window with an auxiliary grid.

Figure 9 shows the decoding process of the encrypted information after the "decrypt" button selecting. There is the decoded text on the left side of the picture, showed in a real time mode. The operator has an opportunity to correct the results of the decoded text by editing individual bits of the image. Saving the image might be done after selecting the "save" button on the hard disk of the PC or on removable media at the user's choice in the txt file, presented in figure 10.

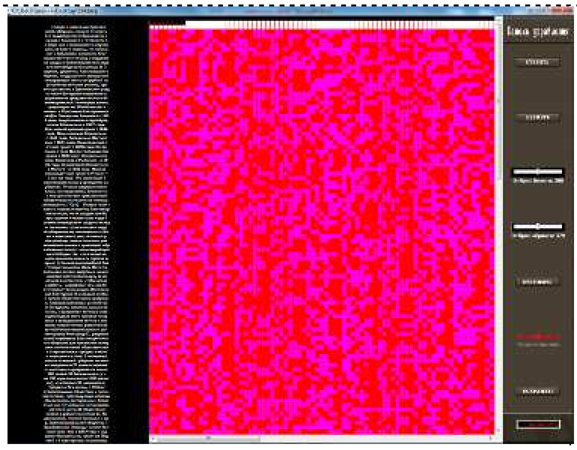


Figure 9. The decoding process.

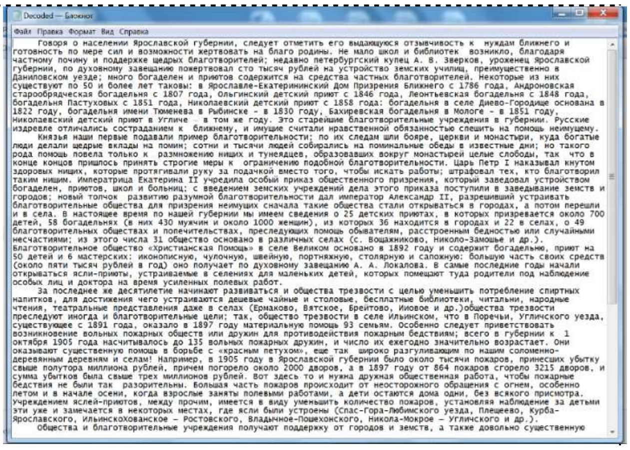
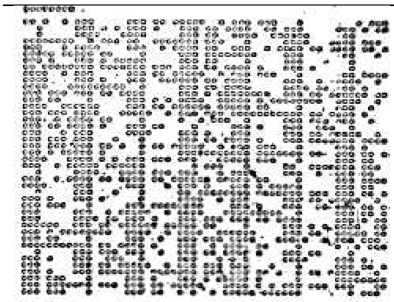


Figure 10. The text file with decoded information.

Thus, the control module, using the decoding program allows decoding the high-density code printed by the pulsed laser on the metal and other surfaces. Table 2 shows the technological regulations for the formation and identification of information fields (high-density codes) on the surface of Iceland spar as an example. The resulting images were scanned, digitized and processed using the original image-decoding program. The accuracy of the information transmission, coded in the high-density code, was 100% on the tested samples.

Table 2. Technological regulations for processinghigh-density codes on the surface of Iceland spar.

High-density code image	Technological regulations of the high-density code formation	Technological regulations of the high-density code identification process
	Lase model DMark-06 Power - 3 W Lamp current - 7.5 A Image resolution dpi - 508 The radiation frequency - 10,000 Hz The delay - 50 ms Image size - 1.95 x 1.50 mm Number of characters - 300 pcs Encoding speed - 2,5 s	Image resolution - 508 dpi Image size - 2.7 x 2.15 mm The increase in the decoding - 1000% The distances between the lines of the auxiliary grid - 50 μm The multiplicity of the number of lines per vertex - 8 The values of the confidence interval of white colour - 462 units and black colour - 461 units Repeatability - 100% Probability of reading is 100% Decoding speed 3,5 s

5. Conclusion

A polygraphic program-controlled hardware system and a process of applying and identifying high-density codes on the surface of products, made from various materials, have been developed and tested. The provided system and process do not have domestic and foreign analogues. The proposed marking technology ensures the placement of a large amount of information on a small area and the successful recognition of the printed high-density code by an original scanning device with de-encryption by the original software of much higher resolving capacity than existing standard scanners of barcode and matrix code.

The approved process realization of obtaining and identifying new generation of high-density codes on an industrial scale will create real prerequisites for a reduction in the counterfeit products production for a wide range of purposes all around the world.

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