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Reliability of Dot Peen Marking in Product Traceability

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Abstract

Implementation of product traceability is in interest of every producer because it cuts production cost and provides better security booth for buyers and suppliers. To provide traceability of product parts it is needed to mark each part separately. Dot peen marking is technology where data is printed on product surface by stamping with carbide needle. Research presented in this paper is focused on readability of DataMatrix 2D code made with dot peen marking method. It includes few types of materials and also different parameters of marking (code size and stamping depth).

Key words: *Traceability / Marking /Dot peen.*

1. INTRODUCTION

Implementation of product traceability is in interest of every producer because it cuts production cost and provides better security booth for buyers and suppliers. In case of reclamation, product traceability provides data which can be used to track product all the way from buyer back to production line or even to product components and raw materials. On the other hand, if producer finds out that entire batch of products is bad, with product traceability is much easier to find out which buyers have those products. This topic is very important in case of products which have influence on human health and those are directly connected to food industry [1]–[3], automotive [4], toy industry [5], etc. Product traceability also helps on the end of product life cycle enabling easier recycling and thus helps in environmental protection [6].

To provide traceability of product parts it is needed to mark each part separately. Basic way of marking is to put sticker which usually have printed barcode [7] or 2D code [8]. This is cheap and easy way to label parts and products. The problem is reliability of this type of marking because sticker can fall off from product or can easily be damaged. Another way of product labeling is use of RFID tag [9] which is usually glued on part needed to be marked. Advantage of RFID tag is fast data reading and possibility of reading from greater distances (few meters). Even more, there is possibility to change or add data to RFID tag. Disadvantage of labeling products with RFID tag is the fact that, like sticker, it can also be damaged. There is also problem of higher cost of needed infrastructure and reliability of reading RFID tag when it is placed near metal object. To avoid using stickers or other elements for product labeling, nowadays producers are more oriented on direct product marking [10] such as ink jet printing, laser engraving, electrochemical etching and dot peen marking. Direct type of product marking enables printing of alphanumeric characters, barcode and 2D code. Ink jet printing provides direct product marking [11] but disadvantage of this method is the fact that marks are not long lasting because they can be damaged or ink can fade. Laser marking [12] and electrochemical etching [13] changes color on the surface of product. This type of marking is more robust, compared with ink jet marking, but on the other hand those systems are very expensive. The possibility of toxic vaporization during laser marking is also one of the shortcomings. Dot peen marking [14] is technology where data is printed on product surface by stamping with carbide needle. Because data is stamped on product surface it is more robust on surface damage. Dot peen technology can be used to print alphanumeric text data (letters and numbers) and two-dimensional codes. The most commonly used two-dimensional codes are Data Matrix codes. Fig. 1 shows dot peened marks on part (two-dimensional DataMatrix code and text).

Figure 1. Example of part marked with dot peen technology

This research is focused on readability of two-dimensional DataMatrix code made with dot peen marking method. Research includes few types of materials and also different parameters of marking (code size and stamping depth). Because of aims to lower costs there is a trend of using smart phone as an auxiliary tool in industry as effect of BYOD concept (Bring Your Own Device) [15] and COTS (Commercial of the Shelf) [16]. Because of those trends readability will be checked with smart phones and industry camera for machine vision.

2. DATAMATRIX CODE

DataMatrix code is two-dimensional code developed by the company RVSI Acuity CiMatrix (company was later acquired by Siemens Energy and Automation, Inc.) [17]. DataMatrix code consists of black and white modules that represent unique finder pattern and encoded data in either a square or rectangular shape. Example of DataMatrix code with unique finder pattern and encoded data is shown in Fig. 2 [18].

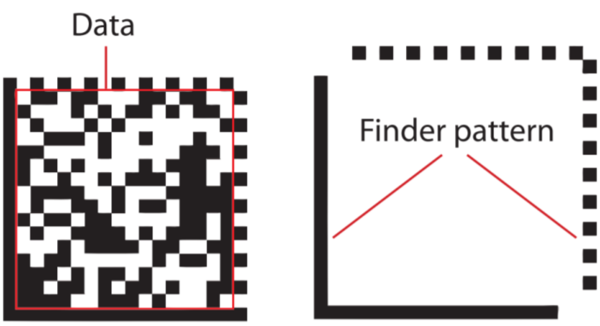

Figure 2. Example of DataMatrix code

Unique finder pattern, placed around the code, is used for orientation and determination of the symbol. Two adjacent sides (left and bottom) are solid dark lines which forms the L boundary. This L boundary is used primarily to determine physical size, orientation and symbol distortion. The two opposite sides (top and right) are made up of alternating dark and light modules, and they are used primarily to define the cell structure of the symbol, but also can assist in determining of physical size and distortion.

DataMatrix is a very efficient and provide high-density of encoded data. Characters, numbers, text and actual bytes of data may be encoded, including Unicode characters and photos. Depending on the size of code, the squareshaped (10 × 10 modules to 144 × 144 modules) or rectangular-shaped (8 × 18 modules to 16 × 48 modules) Datamatrix code can encode up to 2335 alphanumeric data characters, 1555 8-bit byte data character or 3116 numerical data [http://www.gs1.org/docs/barcodes/GS1_DataMatrix_Guideline.pdf]. Datamatrix code can be read even at only 20% of contrast between the printing ink and substrate according to the ISO/IEC 15415.

The encoding and decoding process of DataMatrix is very complex. Several methods have been used for error correction in the past. All current implementations have been standardized on the ECC200 error correction method, which is approved by ANSI/AIM BC11 and the ISO/IEC 16022 specification. The Reed-Solomon error correction algorithms of ECC200 allow the recognition of codes that are up to 60% damaged [19].

3. EXPERIMENT AND RESULT

The readability experiment is consisted of printing two-dimensional DataMatrix codes on plates of three different materials: 0.9 mm thick aluminum plate, 1.2 mm thick steel plate and 2 mm thick stainless steel plate. Two-dimensional DataMatrix codes with different dimension and stamping depth were printed. The integrity of the DataMatrix codes is verified with an industrial camera and a smart phone.

To print two-dimensional DataMatrix codes, handheld device for dot peen marking SIC Marking E1 P63C is used [20]. Fig. 3 shows handheld device for dot peen marking SIC Marking E1 P63c.

Figure 3. Handheld device for dot peen marking SIC Marking E1 P63C

The E1 P63c portable engraving machine is particularly suited for use with heavy or oversized components. Thanks to its portable and compact design, it fits easily into difficult-to-access places. The P63C's dot peen marking machine is driven by electromagnetic technology which drives a tungsten carbide stylus into the surface material. Capable of marking almost any material known to man, the precise, powerful stylus assembly allows for deep, sharp marking, while the generous marking window (60 x 25 mm) allows for the marking of high, easily read characters. SIC Marking's E1 Controller independently operates and manages this marking machine, meaning no PC is required for operation. Initial setup can be done from a PC using the E1V1 software, while the USB port allows file transfer and marking software updates. The E1 was ruggedly designed for industrial applications. It contains no openings or ventilation components providing optimal protection of interior electronic components. The HD color screen features an integrated graphic display, making it easy to navigate. Using the protected membrane keyboard, programming is simple: the E1 allows for the direct change of settings and marking designs via manual input, or pictogram colors. The E1 integrated controller software is used to program all parameters directly through the keyboard (autonomous operation). A Windows tool library also allows programming from a PC. Internal memory of E1 P63C's controller is 100 MB (megabytes) and can store up to 20,000 marking files. Fonts supported by this device are: Courier, 4 x 6, OCR-Bold, OCRA, and OCR. Marking types supported by this device are Linear, Radial, Angular, DataMatrix, and Logo. Speed of marking characters is up to 2.5 characters per second. Minimal size of character is 1 mm. Depth of marking is up to 0.3 mm. The impact force can be adjusted into 9 levels (from 1 to 9). For marking DataMatrix codes in experiments four levels of impact force were used: level 1, level 2, level 3 and level 6. DataMatrix codes are marked in four dimensions: 10.4 × 10.4 mm, 13 × 13 mm, 15.6 × 15.6 mm and 18.2 × 18.2 mm. Impact forces and DataMatrix codes size are determined experimentally based on various tests on different materials and different scanning devices.

Code scanning is realized with FESTO SBSI-B-R3B-F6-R industrial camera [21] and Samsung Galaxy Note 4 SM-N910C smartphone with Android operating system [22]. FESTO SBSI-B-R3B-F6-R is an industrial camera for scanning single-dimensional and two-dimensional codes. This camera has a 736 x 480 pixel (WideVGA) monochrome sensor with integrated red and infrared light source. The camera can decode the following barcodes: EAN, UPC, RSS, 2/5 Interleaved, 2/5 Industrial, Code 39, Code 93, Code 128, GS1, Pharmacode, Codabar, Datamatrix (ECC200), QR-Code and PDF 417. The duration of scanning and decoding cycles for single-entry barcodes is 30 ms and for two-dimensional codes is 40 ms. Samsung Galaxy Note 4 Note 4 features a 16 MP resolution camera with optical image stabilization and integrated LED flash. For the purpose of scanning Datamatrix codes applications iGepir [23] and i-nigma QR & Barcode Scanner [24] were used. Fig. 4 shows experimental setup for scaning DataMatrix codes with FESTO SBSI-B-R3B-F6-R industrial camera. Fig. 5 shows PC application for FESTO SBSI-B-R3B-F6-R industrial camera.

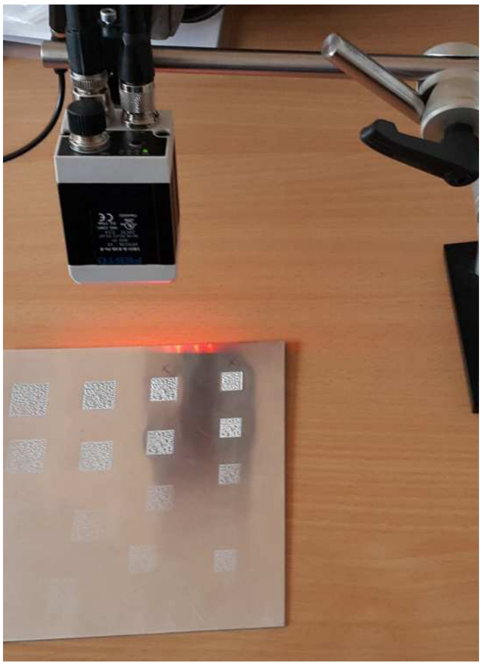

Figure 4. Experimental setup for scanning DataMatrix codes with industrial camera

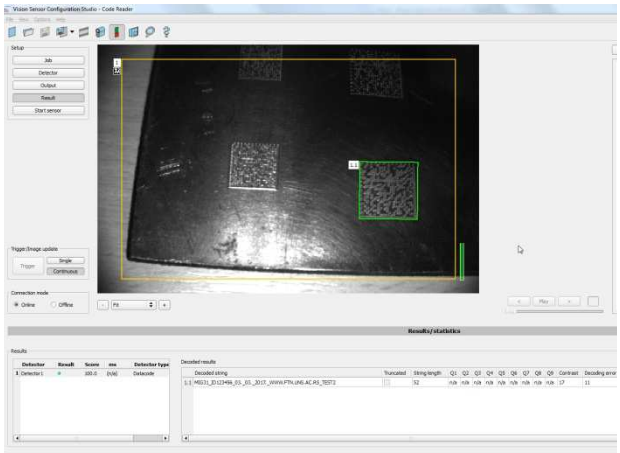

Figure 5. PC application for FESTO SBSI-B-R3B-F6-R industrial camera

The readability results of Datamatrix codes marked on aluminum, steel and stainless steel are given in Table 1, Table 2 and Table 3, respectively. The tables give readability results depending on dimensions of DataMatriks code, impact force, and whether the DataMatrix code is scanned by industrial camera or a smartphone camera. The descriptors in the tables are:

- Dim. [mm] – dimension of DataMatrix code in milimeters,
- IC – a readability test carried out by an industrial camera,

- SP - a readability test carried out with a camera on a smart phone,
- R - result if the decoding of DataMatrix code is successful (readable),
- NR - result if the decoding of DataMatrix code is unsuccessful (not readable).

Table 1. Readibility test for aluminum

Aluminum	Level 6		Level 3		Level 2		Level 1	
Dim. [mm]	IC	SP	IC	SP	IC	SP	IC	SP
10.4 x 10.4	NR	NR	NR	R	R	R	R	R
13 x 13	R	NR	R	R	R	R	R	R
15.6 x 15.6	R	R	R	R	R	R	R	R
18.2 x 18.2	R	R	R	R	R	R	R	NR

Table 2. Readibility test for steel

Steel	Level 6		Level 3		Level 2		Level 1	
Dim. [mm]	IC	SP	IC	SP	IC	SP	IC	SP
10.4 x 10.4	NR	R	R	R	R	NR	R	NR
13 x 13	R	R	R	R	R	NR	R	NR
15.6 x 15.6	R	R	R	R	R	NR	R	NR
18.2 x 18.2	R	NR	R	NR	R	NR	NR	NR

Table 3. Readibility test for stainless steel

Stainless steel	Level 6		Level 3		Level 2		Level 1	
Dim. [mm]	IC	SP	IC	SP	IC	SP	IC	SP
10.4 x 10.4	R	R	R	R	R	NR	R	NR
13 x 13	R	R	R	R	R	NR	R	NR
15.6 x 15.6	R	R	R	NR	R	NR	NR	NR
18.2 x 18.2	R	NR	R	NR	R	NR	NR	NR

Encoded texts with Datamatrix codes are: “MIG31_ID123456_03.03.2017. _WWW.FTN.UNS.AC.RS_TEST1” for aluminum plate, “MIG31_ID123456_03.03.2017. _WWW.FTN.UNS.AC.RS_TEST2” for steel plate and “MIG31_ID123456_03.03.2017. _WWW.FTN.UNS.AC.RS_TEST3” for stainless steel plate.

Experimental results has shown that FESTO industrial camera is suitable for DataMatrix code reading because of integrated infrared light source and good image processing. This enables reliable reading of relative poor quality Datamatrix codes [25]. Camera possess fixed focus lens which means that object must be on fixed distance (around 10 mm deviation is allowed) from camera lens to provide sharp image capturing. Readability with smartphone camera is not so reliable because it depends on many factors. Firstly, smartphone is not equipped with infrared light source which is suitable for this kind of applications. On the other hand image processing depends on used smartphone applications which in general are not developed as industrial software. Globally, experimental results has shown that impact force of dot peen marking, code size and material hardness has high influence on code readability. Two critical cases when code is not readable are:

- High impact force combined with low material hardness and small code size which has a consequence of high material deformation (Fig.5)
- Low impact force combined with high material hardness and bigger code size which results in very small dots with high distance between them (Fig.6)

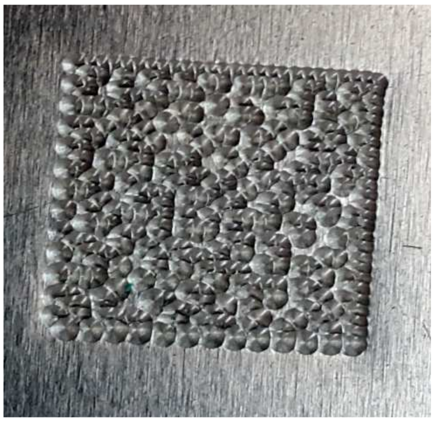

Figure 6. Example of high impact force combined with low material hardness and small code size

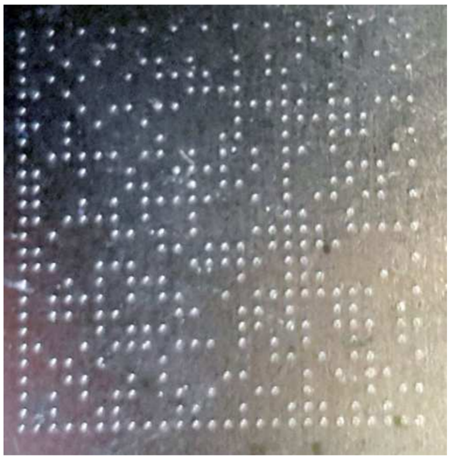

Figure 7. Example of low impact force combined with high material hardness and bigger code size

Regarding DataMatrix code reliability, few cases are taken into account. Usually, after production metal parts are protected against oxidation and corrosion, which means that parts are coated with thin film of oil or grease. This situation is simulated on all three types of material. Experimental results has shown that grease has positive influence on code readability. Applied grease enters into holes which lowers light reflection. Final result is higher contrast between material surface and dots of DataMatrix code. In some cases impurities like dust, rust and oxide can have impact on Datamatrix code and make it unreadable. In these situations simple cleaning of surface with cloth or fine sandpaper can improve code readability in similar way like earlier mentioned case with part conservation. All mentioned situations shows that Datamatrix code made with dot peen method is very reliable resistant to damages.

4. CONCLUSION

This paper shows readability of dot peen Datamatrix codes. It is shown that there is correlation between material hardness, impact force of dot peen and size of Datamatrix code which impacts code readability. Furthermore it is shown that FESTO industrial camera has very good results in image processing and code reading. Despite the fact that smartphones has weaker results of image processing and code reading there is a big potential in this field. In general it is found that impurities (grease, oil, dust, rust, oxide, etc.) can have positive impact on dot peen Datamatrix code readability.

Future research in this field will include analysis and mathematical correlation between material hardness, impact force of dot peen marking device and code size. Furthermore it is planned to develop light source module for smartphones and dedicated application to improve dot peen Datamatrix code readability.

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Pouzdanost tačkastog obeležavanja iz aspekta sledljivosti proizvoda

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Apstrakt

Implementacija praćenja proizvoda je u interesu svakog proizvođača, jer smanjuje proizvodne troškove i pruža bolju sigurnost kako za kupce tako i za dobavljače. Da bi se obezbedila sledljivost elemenata proizvoda, potrebno je svaki obeležiti ponaosob. Tačkasto označavanje (Dot Peen) je tehnologija u kojoj se podaci štampaju na površini proizvoda uz pomoć karbidne igle. Istraživanja predstavljena u ovom radu su fokusirana na čitljivost DataMatrix 2D koda kreiranog metodom tačkastog markiranja, a uključuju nekoliko vrsta materijala, kao i različite parametre obeležavanja (veličina koda i dubina štampe).

Ključne reči: *Sledljivost, označavanje, “Dot peen”*