EXPERIMENTAL VERIFICATION OF THE MECHANICAL RESISTANCE OF FORENSIC MARKING BY MEANS SYNTHETIC DNA

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Research article

Abstract: This article deals with experimental verification of resistance of forensic identification marks (microdots in combination with artificial DNA) to property. It is considered mechanical abrasion from potential offender to remove or damage readability of marking and following identification. The aim of this work is to test the hypothesis that forensic marking can be completely removed by the process of mechanical abrasion without causing damages to a protected object. To fulfill this purpose it was designed and built a test equipment, where experiments were carried out to confirm or refute the above mentioned hypothesis.

Keywords: Forensic identification marks, Microparticles, Synthetic DNA, Experimental Test Equipment, Ultraviolet.

Nomenclatures

FIM	Forensic identification marks.
S-DNA	Type of forensic identification marks, consisted of a combination of synthetic.
DNA	And microparticles, utilised in the structural composition of liquid.
ETE	Experimental Test Equipment.
UV	Ultraviolet.

Introduction

Forensic identification marks (FIM) are a unique form of an authentic identification of an object or device, giving them preventive protection against theft. (Forensic marking, 2015) Ase there is a wide range of FIM types, the authors of this article focused on an assessment of a mechanical resistance of forensic marking by using synthetic deoxyribonucleic acid (DNA) and microparticles coated with a unique optically readable code.

Organic DNA is a double twisted polynucleotide consisted of two single chains of deoxyribonucleic units. It exists in all living organisms (in some cases of viruses is applicated ribonucleic acid - RNA). (Alberts, 1998)

Synthetic DNA is made with artificially produced DNA fibres, having the same chemical structure as the organic DNA, but it is formed by short chains, thus it is much more stable than it is in the case of human DNA. (SelectaDNA advanced forensic marking, 2012)

Synthetic DNA is usually applied to the subject in the form of a thin film (varnish), containing a milky-white, non-toxic fluid with DNA code. The varnish with synthetic DNA then solidifies and creates a layer of thickness about 0.1 mm. Such protected material is then invisibly, permanently and uniquely identified. In order to identify the marked position, an UV lamp can be used.

Some commercial products form a combination of synthetic DNA and another element of forensic marking, such as microparticles. This microparticles are utilized in structural composition of the liquid, together with synthetic DNA. (Koníček, 2011) This set (S-DNA) was also used to verify the following hypothesis.

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Materials and methods

Determination of the hypotheses

Taking into consideration specific properties of the synthetic DNA in combination with the application of the microparticles for forensic marking objects an important question raises:

Is it possible to remove mechanically (e.g., abrasive) the method of marking S-DNA without any visible damage to the protected object?

To answer to this question it is necessary to confirm the following hypothesis:

The thickness up to 0.1 mm of S-DNA can be removed without any damage to the marked subject. That might be achieved by removing of all identifiers contained in S-DNA (varnish with UV brand and synthetic DNA microdots).

For testing the resistance of S-DNA against the abrasive effect an experimental test equipment (ETE) was proposed. The ETE enables to control the varnish removal from the testing target, coated with S-DNA. The ETE diagram is shown in Fig. 1. Subsequently the amount and readability of microdots on the target were verified by using a digital microscop. ETE works on the principle of gravitational pressure of the rotating test target to the oppositely rotating grinding wheel (abrasive disc). (Los, 2015)

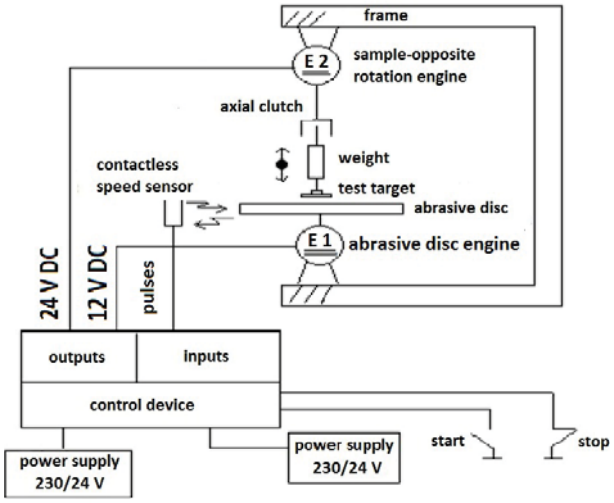


Fig. 1 ETE diagram (Los 2015)

Testing methodology of mechanical resistance of S-DNA

Testing of the resistance of S-DNA against abrasive effect was designed the way that the varnish layer of thickness of approximately 10 microns was gradually being removed by ETE.

After removing of each varnish layer, the number of microdots and their readability were checked by microscope and the reaction of the synthetic DNA to UV exposure were checked. At the same time after each removal of varnish an indicative thickness of remaining measured layer of applied varnish was carried out. This process was repeatable physically under the same conditions.

Actual testing process of the resistance can be divided into the following steps:

1. The simplified ETE confirmation.
2. A controlled abrasion of sample S-DNA.
3. Evaluation of the effect of abrasion on the sample of the S-DNA. (Los, 2015)

Simplified ETE confirmation

Before starting the experiment to confirm or refute the stated hypothesis, it was necessary to determine the size of removal of the varnish on the test sample. The size of removal of the varnish depends on the number of revolutions of the grinding wheel.

The method of ETE simplified confirmation was developed for this purpose. This method served to determine the appropriate number of cycles on ETE, which gradually removed the individual layers of S-DNA until the final removal of varnish on the test target disc. Measurements were made on two different metal targets. Confirmation was done on the acrylic varnish, which had almost the same composition as varnish base of S-DNA. The number of measurements n = 10 was chosen in order to ensure the reliability of the estimation of the input (measured) values. There was no need to load a correction to the number of measurements.

Three methods were used to calculate the standard uncertainty of measurement: A, B, C.

Calculation of the standard uncertainty u_A of the procedure A was performed according to formula (1):

$$u_A = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n \cdot (n-1)}} \qquad (1)$$

where n is number of measurements, $\bar{x}$ arithmetic mean, x_i measured value (for instance axial height targets without varnish.

Artithmetic mean is calculated by following formula number (2):

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad (2)$$

Calculation of the standard uncertainty u_B according to the procedure *B* was not determined via statistical methods, but it was based on knowledge of physical properties of the measuring chain and known or estimated precisions of the used instruments (Palenčár, 2001). Calculation of the standard uncertainty u_B (process *B*) was performed according to formula (3):

$$u_B(z_j) = \frac{z_{jmax}}{k} \tag{3}$$

where z_{jmax} is maximum deviation from the nominal value of the measured parameters associated with the resource of uncertainty z_j, k is a value corresponding to the selected approximation of the probability distribution.

In this case, we considered only the sources of uncertainty concerning the screw micrometer and uniform distribution.

Standard combined uncertainty (procedure *C*) combined the partial uncertainties u_A and u_B by summation of quadrates of its components into the final uncertainty (4):

$$u_C(x) = \sqrt{u_A^2(x) + u_B^2(x)} \tag{4}$$

In practice, there is more efficient to set the final combined uncertainty by interval *U*, in which there was a little probability that it will be exceeded. In case of normal probability distribution the coefficient $k = 2$ is commonly used (see formula 5):

$$U = k \cdot u_C \tag{5}$$

The thickness of the applied varnish L_{var} was determined according to the formula (6):

$$L_{var} = L_{T+\text{var}} - L_T \quad [\text{mm}] \tag{6}$$

where L_{var} is thickness of varnish [mm], L_{T+var} axial height of targets with varnish [mm], L_T is axial height targets without varnish [mm].

Measurement of thickness varnish removal layer L_{dif} after each abrasion cycle (each cycle abrasion was applied ten times) was carried out according to formula (7):

$$L_{dif} = L_{T(n-1)} - L_{T(n)} \quad [\text{mm}] \tag{7}$$

where L_{dif} is size of the varnish removal of *n*-th abrasion, $L_{T(n-1)}$ is axial height of target of (*n*-1) th abrasion, $L_{T(n)}$ is axial height of target of *n*-th abrasion.

Uncertainty of the thickness of varnish $U_C(L_{dif})$ was calculated according to the formula (8):

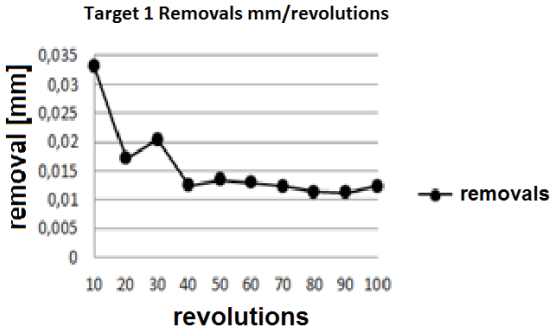
$$U_C(L_{dif}) = \sqrt{u_{C\,LT}^2 + u_{C\,LT+var}^2} \quad [\text{mm}] \tag{8}$$

where $u_{C\,L_T}$ is a standard uncertaity of the axial height of the target vithout varnish, $u_{C\,L_{T+var}}$ is a standard uncertaity of the axial height of the target vithout varnish.

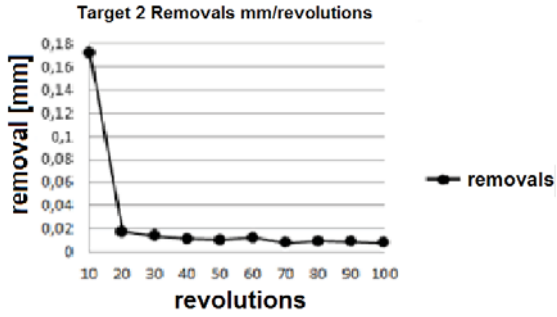
Calculation of the expanded uncertainty height of varnish $U(L_{dif})$ as a result of the operation of the difference axial heights was provided according to formula (9):

$$U(L_{dif}) = U_C(L_{dif}) \cdot k \quad [\text{mm}] \tag{9}$$

Dependence of the varnish thickness removal and the number of revolutions of the targets 1 and 2 show graphs 1 and 2.



Graph 1 Dependence of the varnish thickness removal and the number of revolutions of the target 1



Graph 2 Dependence of the varnish thickness removal and the number of revolutions of the target 2

The simplified confirmation proved the varnish removal in the range of 8-21 microns with uncertainty in the range of 3 to 5 micrometers per every grind cycle (10 revolutions of the grinding wheel) of ETE, in the interval from 20 to 100 revolutions of the two different targets. During the test of the mechanical resistance of S-DNA 10 revolutions were used per every grind cycle.

Testing of mechanical resistance of S-DNA

The aim of the test of mechanical resistance was to obtain data for making a decision the the hypothesis regarding the resistance of S-DNA to abrasion. Following variables were chosen:

- Number of microdots before and after of each abrasion.
- Readability of microdots.
  - Good - you can read the entire length of the alphanumeric code.
  - Partial - readable is a part of the length of the alphanumeric code.
  - Insufficient (unreadable)- alphanumeric code can not be read.
- Reaction of the test targets with synthetic DNA to UV exposure.

Used apparatus:

- USB microscope with resolution - 12 megapixels, 20 to 200 times magnification.
- ETE.
- Digital screw micrometer T5.
- Typesetter UV-LED unit with following parameters: 4 x 3 mm LED 390 ~ 400 nm, 2000 uW 25 ° ~ 35 °, 3.5 ~ 3.8 V 20 mA clear, 24 V DC with using of resistors.

Testing of the mechanical resistance of S-DNA was performed on two steel targets which differ in their geometrical dimensions. Drawing of the both targets is shown in fig. 2. The marked target was applied to S-DNA using the original applicator. Target surfaces were abraded on ETE at 100 revolutions before the application of S-DNA.

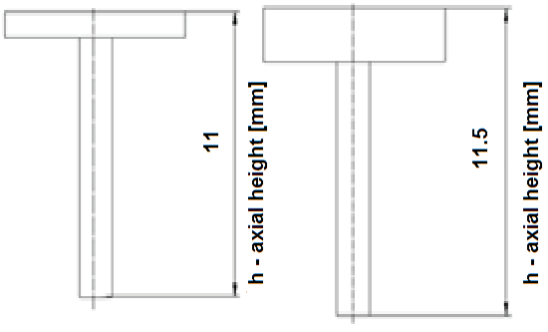


Fig. 2 Drawing of the both targets

Results

There is demonstrated data processing for targets coated with DNA bellow (Tab. 1).

Tab. 1 Overview of the data of the targets coated with S-DNA (Los, 2015)

Brown target						
Revolutions	**Varnish thickness [mm]**	**Number of microdots**	**Number of good readable microdots**	**Number of partial readable microdots**	**Number of unreadable microdots**	**UV reaction**
0	0,097	4	3	0	1	Yes
10	0,0811	4	0	0	4	Yes
20	0,0654	3	0	0	3	Yes
30	0,0574	3	0	0	3	Yes
40	0,0497	3	0	0	3	Yes
50	0,0442	3	0	0	3	Yes
60	0,0376	3	0	0	3	Yes
70	0,0309	1	0	0	1	Yes
80	0,0228	1	0	0	1	Yes
90	0,0191	1	0	0	1	Yes
100	0,0158	0	0	0	0	Yes
Pink target						
Revolutions	**Varnish thickness [mm]**	**Number of microdots**	**Number of good readable microdots**	**Number of partial readable microdots**	**Number of unreadable microdots**	**UV reaction**
0	0,1032	4	2	2	0	Yes
10	0,0679	4	0	0	4	Yes
20	0,0594	4	0	0	4	Yes
30	0,0517	4	0	0	4	Yes
40	0,0428	4	0	0	4	Yes
50	0,0357	4	0	0	4	Yes
60	0,0287	4	0	0	4	Yes
70	0,0232	4	0	0	4	Yes
80	0,0178	0	0	0	0	Yes
90	0,0126	0	0	0	0	Yes
100	0,0088	0	0	0	0	Yes

Conclusion

Based on the data presented in Tab. 1, the hypothesis regarding the removability of S-DNA cannot be confirmed. It is impossible to remove S-DNA by simulation of mechanical abrasion. The marked object remains recognizable by the synthetic DNA, contained in the rest of the varnish. Although the first grind cycle prevented the readability of microdots, there was only an increase in the time and expense to the identification of the designated product. Abrasion causes an illegibility of microdots and after prolonged exposure it can cause their loss from the varnish base.

Therefore, it may be problematic to use S-DNA at locations with increased exposure to abrasive effects of environment, such as wheels or unprotected parts on the body of the car. If S-DNA in not completely removed, even small remnants react to UV radiation and thus we can assume that these residues contain synthetic DNA, applicable for any forensic analysis.

Results obtained in the above mentioned experimental measurements demonstrate a high level of protection provided by the synthetic DNA in combination with microdots. The anti-theft protection can be applied to a wide range of subjects with high value, such as unmanned aerial vehicles, cars and other technical devices.

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