COMPUTED TOMOGRAPHY IN FORENSIC RESEARCH

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Abstract: The paper is focused on using computed tomography in forensic research and the performance of computed microtomograph Skyscan 1272. Computed tomography due to its non-destructive analysis of the internal structure of materials can be applied in many fields. This method also provides information on the distribution of fillers, pores, fibers and defects in the tested sample and their 3D visualization using specialized software. Computed microtomograph Skyscan 1272 can be successfully used in forensic investigation of an attacked seals. For example during unauthorized consumption of energy and water supply, in the tempering with security seals and a consequent theft, in logistics, in the transport of cargo and money, in the counterfeit goods (trademark protection, seals, stamps) etc. Computed tomography is able to verify and detect unauthorized tempering with the security seal, stamps and envelopes.

Key words: computed tomography (micro-CT), 3D visualization (3D model), forensic research, security components

1 Introduction

Computed tomography is a radiological examination method that allows displaying an internal structure of materials using x-ray radiation. CT can be translated into imaging in cuts, in other words displaying the structure without physical disruption of the whole. This method is currently widely used, for example in medicine, archeology, biology, geophysics and many other fields of science. It is based on a mathematical method known as tomographic reconstruction [1]. The resulting image quality is dependent not only on time the data are processes, but also on other factors. X-rays weaken while penetrating various materials. The degree of their absorption is either smaller or greater depending on the density of the material and depends mostly on the properties of the examined material.

This X-ray diagnostics can be successfully applied in forensic examination of a damaged seal in these situations:

- *Unauthorized access of energy and water grid* – deliberate attack of measuring instruments (water, electric and gas meters), damage to security seals (led, plastic, self-adhesive) in order to eliminate or limit measuring equipment and to illegally withdraw the medium.
- *Forensic science*– manipulation with security seals in order to enter into secured premises and subsequent theft.
- *Logistics, freight and money transfer* – manipulation with security seal in order to enter into secured premises and subsequent theft.
- *Hunting*– manipulation with security seal for the purpose of stealing the game, poaching (in the Czech Republic and in a number of European countries it is mandatory to mark the killed game by a seal with the number of a hunting association on whose territory the game was hunted down).
- *Product forgery* – brand protection, seals, stamps.

The aim of this article is to present particular equipment of the computer tomography Skyscan 1272 and demonstrate its utilization in the field of forensic science [2].

2 Methodology and means for solving the problem

Using computer tomography we can easily and nondestructively visualize structures of the observed objects, such as composite materials, tissue, bones, spacer knitted fabric, non-woven textiles, biological materials etc.[4]

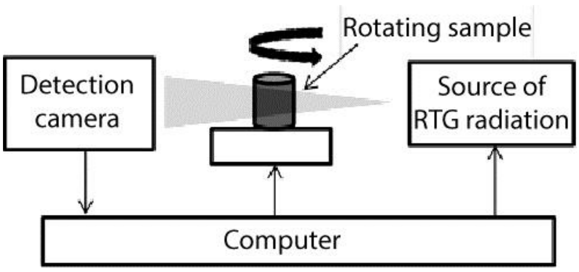

Fig. 1 The diagram of x-ray microtomography function

Figure 1 presents x-ray microtomograph function [4].X-ray RTG imaging is achieved by the rotation of the tested sample and x-ray radiation emitted under various angles. CCD detection camera is localized opposite of the x-ray emitter. Thin stream passes through the sample and its intensity is detected and transferred into electrical signals. X-rays weaken while passing through various materials. The degree of absorption is smaller or greater depending on the density of the material and depends mostly on the properties of the examined material [3]. Absorption represents the ability of various substances to absorb x-ray radiation. In case the emitted energy is constant, the absorption of x-ray radiation depends only on the material they pass through. The output of the tomograph is represented by 2D images (cuts).

This method can be used to check the material, localize defects and faults of the inner material structure, material density, relative content of components in different sections of the cut, pore or object distribution, visualization of the examined structures etc. [2].

2.1 Experimental technique

Desktop microtomograph Skyscan 1272 (fig. 2) contains an x-ray emitter with the output of 10 W max, 16Mpx detection CCD camera, support to fix the sample and a computer terminal. The resolution of the device is 0,5 µm, maximum size of the tested material is 70 mm in diameter and 70 mm in length.

Method of testing the inner material structures is as follows:

Skyscan 1272 scans the object in the form of 2D images and transforms the object into 3D form using specialized software (reconstruction software NRecon). Obtained dataset and scanning results can be verified using program Dataviewer, allowing for detailed inspection of the inner structures of the tested sample from three axes – transaxial, sagittal and coronary. Part of the tomograph is also a software suite for complete 2D and 3D quantitative analysis, for morphometry (measurement of shapes) and densitometry (for the measurement of optical densities of the computed photographic images), for realistic 3D visualizations of the examined objects (creation of 3D models), etc. [4].

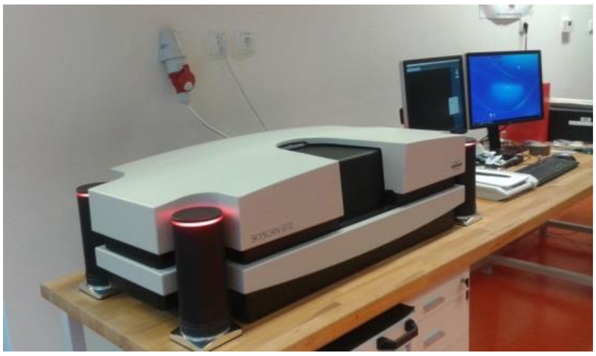

Fig. 2 Microtomographic device SkyScan 1272 including the workstation

2.2 Used materials and methods of measurement

Security components by the company Euroseal a.s. Liberec were used for the evaluation and visualization:

- indicative plastic seals of the PL type with wide range of use, manufactured from high quality plastic material,
- plastic seals of the ES type manufactured from high quality plastic material with the addition of metal collet,
- metal cable seals, with body made of aluminum and a seal sealed by metal cable,
- metal container seal made of high quality steel.

One group of security seals was modified in order for the sample dimension to correspond with the required parameters suitable for microtomograph Skyscan 1272. Samples were inserted into the scanner and fixed with rotational support. Scanning process was initiated after setting respective scanning parameters. After the scanning finalization an obtained 2D dataset was transferred into 3D dataset using NRecon software. Such transformed data were further processed using Dataviewer and CTVox programs. Second group of the selected security seals was exposed to heat, mechanical or chemical deformation. Those damaged seals were scanned and the obtained data processed by special software. Plastic seals were subjected to temperatures of 185°C and 120°C or chemically deformed using technical petrol and polyoxymethylen, metal cable seals were mechanically strained by 1, 2, 3, and 4,4 kN. Several obtained images of the undamaged and damaged security seals are presented in the following chapter 4.2.

3 Results and discussion

3.1 Visualization of the undeformed security components

A. Plastic security seals of the PL type

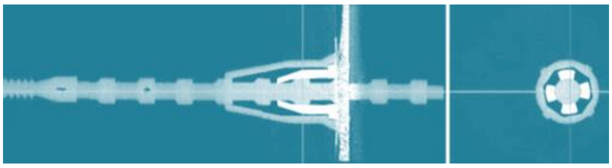

Fig. 3 Plastic security seal of the PL 91 type

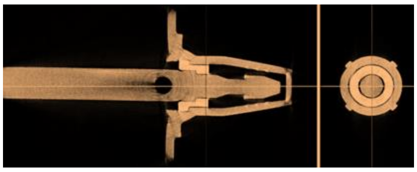

Fig. 4 Plastic security seals of the PL 95 type

Scanning parameters for the PL type security seals:

- ✓ X-ray voltage 50 kV, current 200 uA, resolution 20 um, exposition 464 ms, scanning duration 35 minutes.

B. Plastic security seals of the ES type

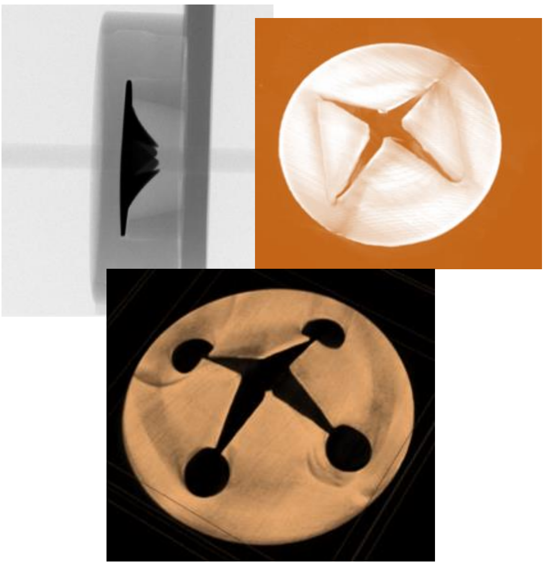

Fig. 5 Sample of the plastic security seals of the ES type

Scanning parameters for the ES type seal:

- ✓ X-ray voltage 80 kV, current 125 uA, resolution 20 um, exposition 1129 ms, scanning duration 200 minutes.

C. Metal cable seals

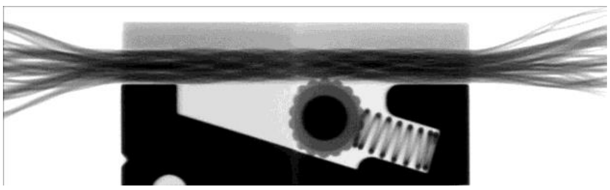

Fig. 6 Visualization of the metal cable seals

Scanning parameters for the metal cable seals:

- ✓ X-ray voltage 100 kV, current 100 uA, resolution 20 um, exposition 2130 ms, scanning duration 70 minutes

D. Metal container seals

This security component cannot be tested by the tomograph because of insufficient output of the X-ray. An image provided by the scanner is available.

Fig. 7 Image provided by the scanner – metal cable seal

3.2 Visualization of the deformed security components

A. Thermal deformation of the security components at 120°C

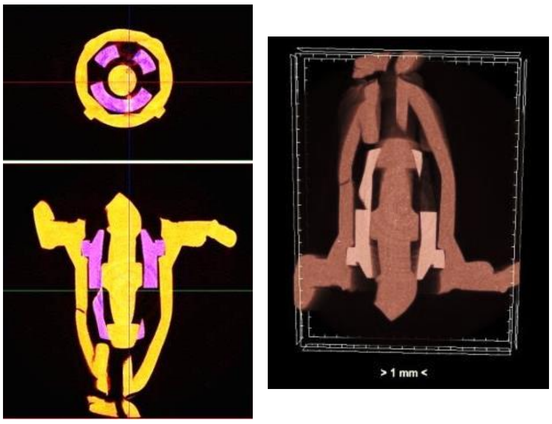

Fig. 8 A cut through seal of the PL type deformed by heat (120°C) and a 3D model of the destroyed seal

B. Thermal deformation of the security components at 185°C

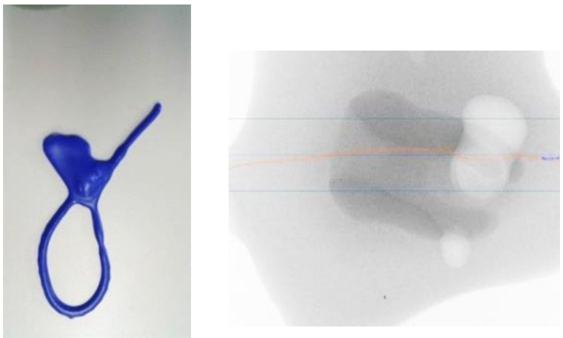

Fig. 9 Photo of a badly damaged seal of the PL 91 type and a view provided by the tomograph into the structure of the security component damaged by thermal deformation (185°C)

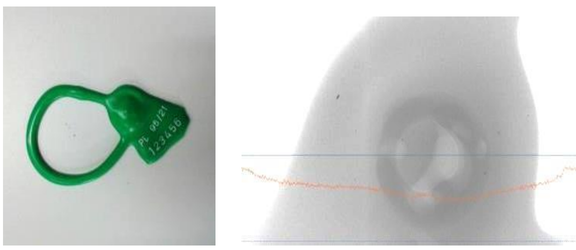

Fig. 10 Photo of the damaged PL 95 type seal and a view into the structure of the security component after thermal deformation (185°C)

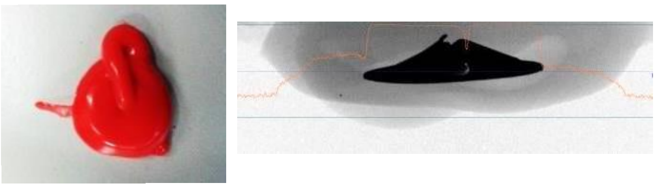

Fig. 11 Photo of the damaged ES type seal and a view provided by the tomograph onto the structure of the security component after thermal deformation (185°C)

C. *Tensile deformation of the security components*

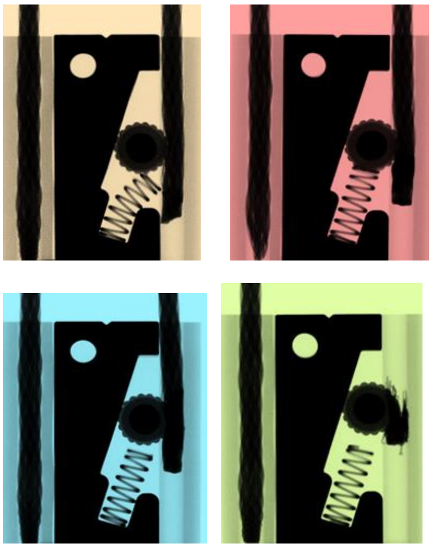

Fig. 12 Visualization of the tensile deformation of the metal security components (strained by 1, 2, 3 and 4.4 kN – from left to right)

Chemical deformation of the security components

- deformation by the technical petrol

Fig. 13 Seal visualization marked by thermal print and damaged by technical petrol

- deformation by the Polyoxymethylen

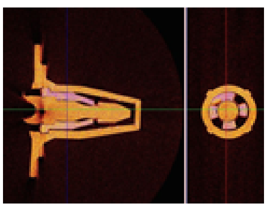

Fig. 14 Visualization of the PL 95 type security seal after chemical damage cause by Polyoxymethylen

4. Conclusion

Three levels of examination are applied while examining potentially attacked security seals in order to find out their actual state. The first level is a visual examination, taking place at the location of an attack and doesn't usually use any other means. The second level is an inspectional examination, which takes place at the location of an attack or in laboratory conditions. It is possible to use other equipment (such as magnifiers, microscopes and reference sample). This research is conducted by specially trained person. The third level is a forensic research conducted in laboratory conditions with a specially trained researcher using special equipment. Conclusions of forensic research can be used as proof during a lawsuit. A sophisticated computed microtomograph was presented here as one of the ways of non-destructive examination, detection and verification of unlawful tempering with security components.

5. References

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