

Quality analysis of mechatronic components using industrial tomography

Peter Kat'uch¹, Jozef Živčák², Miroslav Dovica³, Jozef Kováč⁴

¹ Technical University of Košice, Letná 9 Košice, +421 55 602 3224, peter.katuch@tuke.sk

² Technical University of Košice, Letná 9 Košice, +421 55 602 2380, jozef.zivcak@tuke.sk

³ Technical University of Košice, Letná 9 Košice, +421 55 602 3224, miroslav.dovica@tuke.sk

⁴ Technical University of Košice, Letná 9 Košice, +421 55 602 2656, jozi.kovac@tuke.sk

Abstract-Computer tomography is well known term in a medical area for many years. Nowadays the computer tomography starts to be better known also in areas of mechanical, automotive, mechatronic, electric and electronic engineering. With this technology non-measurable parts can be measured and assemblies can be controlled without destruction or dismounting. This paper deals with application of computed tomography in area of electrical engineering products inspection.

I. Industrial computer tomography

By the invention of the X ray radiation at the end of the 19th century, these rays started to be used mainly for diagnostics and control of the inaccessible places for human's eye. Its important characteristic is transition through solid substances. The quality of the radiation intensity is decreasing depending on the material's absorbing characteristics and cumulative thickness. In such a way, we can diagnose the errors in the materials, control the human organs, control the content of the luggage at the airport, etc.

Only when in the 70's of the last century the IT improvement came, it helped to start using X-ray radiation for 3D diagnostics. Thanks to computed tomography (CT) it was possible to create virtual section of the volume model of the scanning body without any abolition. Computed tomography was firstly used in the medicine. In the upcoming years, its use was spread and so the process of the improvement was accelerated. By the development, the picture quality and resolution are improved, radiation load is decreasing and examination time is shortened

In the last years, the computed tomography was introduced to the industrial area. Industrial CT machines are conceived differently than medical tomographs. Whereas the scanned parts are more often of the solid structure, it is not imperative to place them into the static position (when the detector and the source of Rontgen radiation are rotating) and also it is not necessary to limit the radiation load significantly.

Consequently, the industrial tomographs are typically of the same construction. Measured part, which is rotating around the vertical axis, is situated between the source of the X-ray radiation and the detector that changes radiation to the electric signal (information). The rontgenograms (the X-ray pictures) are being captured in particular steps during the rotation of the measured part. The reconstruction software creates the 3D model of the real part, from those rontgenograms (hundreds of pictures), in the shape of bunch of spots. We can find those spots called voxels (volume pixel) ordered in the space and, for example, we can assign 16-bit information about the absorbing characteristics of the real part in this position to them. In the virtual environment, this information is shown as a particular level of grey colour. In the present time of the industrial tomographs construction, the resolution of the detector is approximately 1024x1024 pixels which is the data file with the information about the scanned space with the size of 2 GB of data. Besides, the tomographs with the resolution of 2048x2048 pixels have the data volume approximately equals to 16 GB.

Nowadays, the industrial tomographs are designed to scan with the high precision. Thanks to this, their use will be extended from the diagnosis area to the metrology area. In the metrology, they will improve the control of the shapely-complicated parts that could not have been measured until now. We can speak about the parts in the terms of inaccessible areas for conventional measuring technology. Carl Zeiss company as the one of the industrial tomographs producer gave a name to this technology – Metrotomography. It is the combination of two terms: metrology and tomography. The main metrotomography areas of the use are:

- testing:
 - quality of the joints in the sets
 - analysis of the porosity
 - analysis of the failure
 - inspection of the material
- measuring the diameters of the inner and outer articles
- backward engineering (obtaining the CAD model of the real part)
- comparing the total geometrics with the real (scanned)

II. Inspection of the electric, electronic and mechatronic systems

In the area of electrotechnics, electronics and mechatronics, this technology can be used for diagnostics and the shape of the parts control, exact positioning of the articles in the assembly, integrity and porosity of the material, identification of broken parts and the short circuits in the electric networks, etc.

In many cases, the sudden state change happens while producing and also after introducing the parts into operation that may lead to the system malfunction or emergency case. Many times, it was not possible to identify the cause of the failure without distortion. Distortion methods are not only irreversible but also they cause that the part is not useful anymore. They can also cause that the problem will not be solved therefore using the distortion way the problem may change or may be completely eliminated.

Often, this kind of situations happen while constructing many parts on the assembly line where there the relative position of the parts is not kept and while contracting the final product we can face the deformation, breakage or incorrect positioning of the particular parts of the sets. As an example we can take the constructing the rotor and stator part of the electromotor where by the influence of deviations of contact position we can face the plastic deformation of the brass contact and its unfitting the required position (fig. 1). Thanks to the computed tomography, it is possible to visualise the scanned motor and to show the areas, which are in the centre of the interest, in 3D by the virtual component elimination. It is possible to cross the area of bunch of spots using the section plane in the random direction or to show the bunch of spots as a 3D picture.

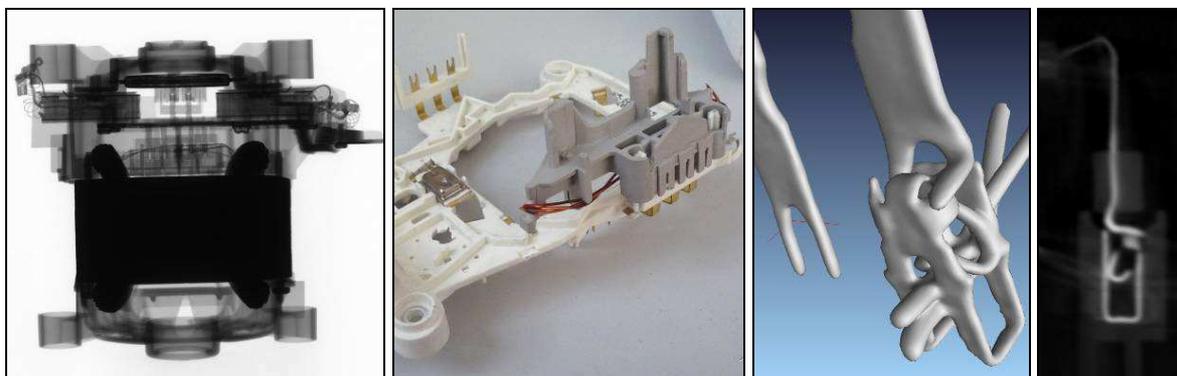


Figure 1: Engine from washing machine a) x-ray picture b) demounted parts of interests
c) rendered point-cloud of connectors d) cross-section image of connectors

The industrial tomography is indispensable in the area of process assembly control. During the process of parts setting into the production, it can happen that prototypes or first products serve to an adjustment of the producing and installing machines. The diagnosis of the exact positioning of the elements is extremely important. Apart from non-contiguous electric contacts, incorrect fit of the mechanical part of the set can occur. Generally, we are talking about functional parts of mechatronic sets or machine covers or handles. In the picture, the instrument panel of the automobile is shown. In the middle, the set is shown by two section planes and on the right side, there is a picture viewing the metal parts inside the set after the translucency of materials with lower density.

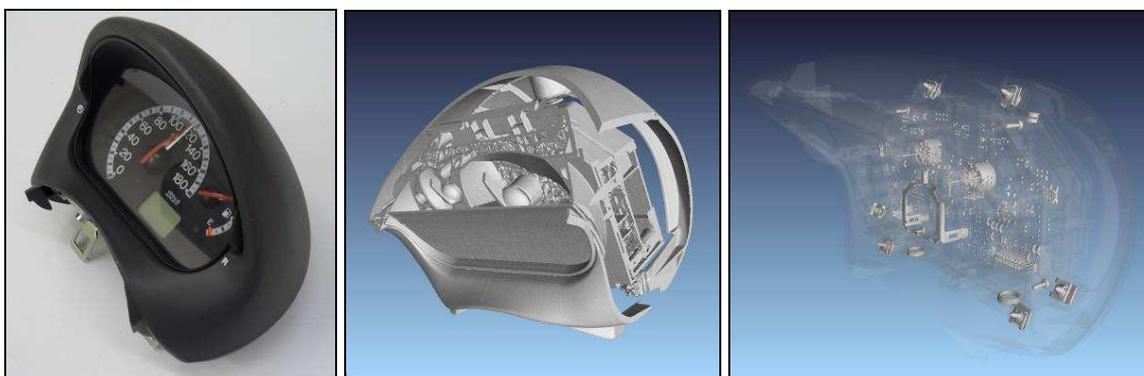


Figure 2. Dashboard from automobile a) real dashboard, b) virtual cross-sections of dashboard,
c) translucency of non-metal parts of dashboard

Besides the product control in the phase of prototyping and introducing into production, the causes of distortion arise or emergency case, when the critical part of body is destroyed, are being evaluated. For examination of the causes of the emergency cases, any kind of interruption of this process is ineligible. The non-destructive tomographic examination is offering the inside view, by classical analysis of the Rontgen picture in the real time or by the reconstructive bunch of spots, to study the scanned volume by sequential movement through section planes in any direction. Another possibility is to create the render 3D picture with the possibility of video recording and dimensional movement through the bunch of spots by any section plane. In the picture, these three possibilities are shown on the example of torrid capacitor (fig. 2).

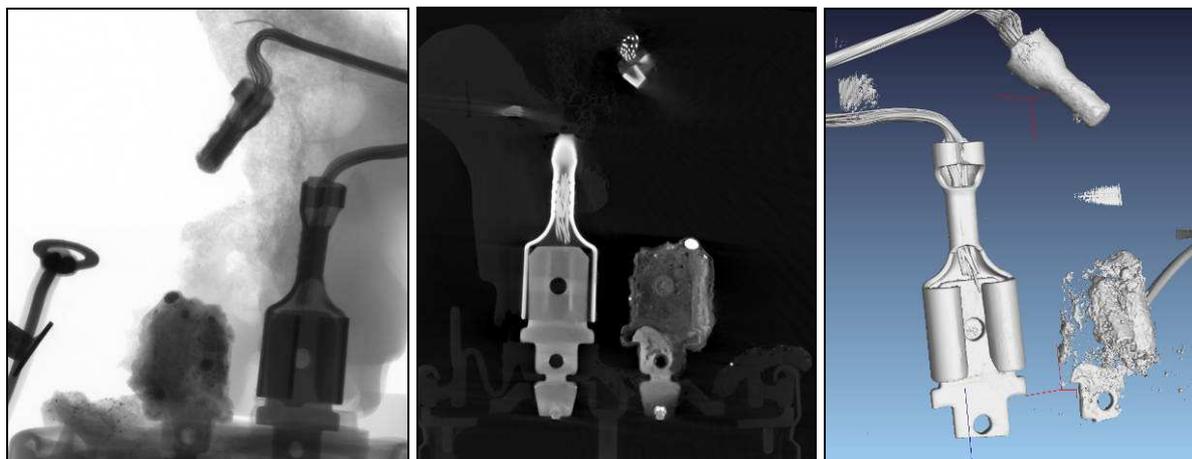


Figure 3. Destroyed capacitor a) x-ray picture,
b) cross-section picture of point-cloud, c) rendered image of point cloud

As it was already mentioned, the value represented by certain level of grey colour (according to material density) belongs to every spot in the bunch of spots. All of the spots from the bunch can be sorted according to multitude and colour scale and can be shown in the form of histogram. From the histogram, we can define the representation of the omnigenous materials in the whole bunch of spots. During the visualisation, the display of several materials can be suppressed. As an example, we can mention the tachoreel shown in the picture, where the problem in the integrity of copper winding was identified during the check-out. When the control by multimeter was done, the suspension of the wire was signalled, however, the problem arrived while defining the place and extent of suspension. After the tomographic examination, the place of suspension was found by the virtual elimination of the plastic connector covers.

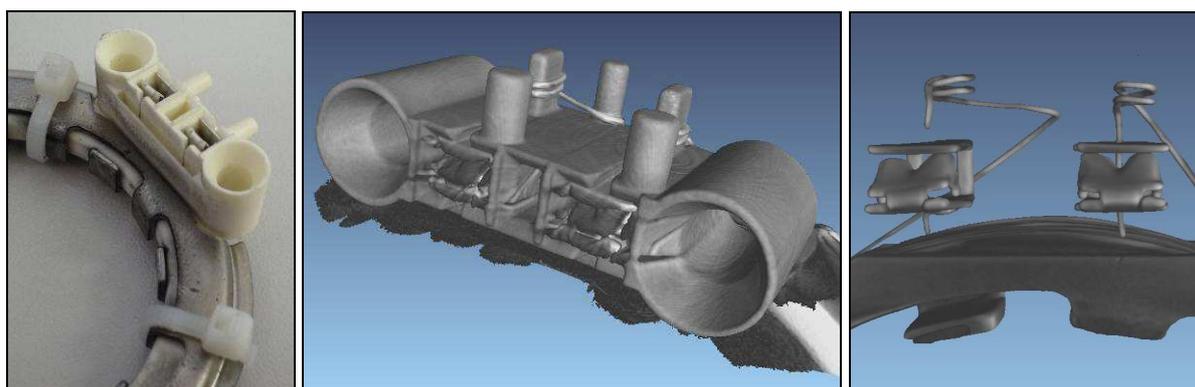


Figure 4. Tacho-reel a) real part, b) point-cloud of connector, c) separated plastic cover of connector

The printed circuits boards are frequent subjects of control. Integrated circuits that are contacted to board of printed circuits along the periphery are, in many cases of optic control, being monitored by microscopic technique. Integrated circuits with covers, whereas the contact with mother-board under integrated circuit is being made, cannot be controlled by usual optic methods. They are often controlled by machines using the Rontgen radiation. Using the computed tomography, it is possible to divide the omnigenous materials in the

bunch of spots, representing scanned body, and so to show only the material of conjunct. According to the shape of conjunct, we can identify whether there is a contact between the integrated circuit and mother board.

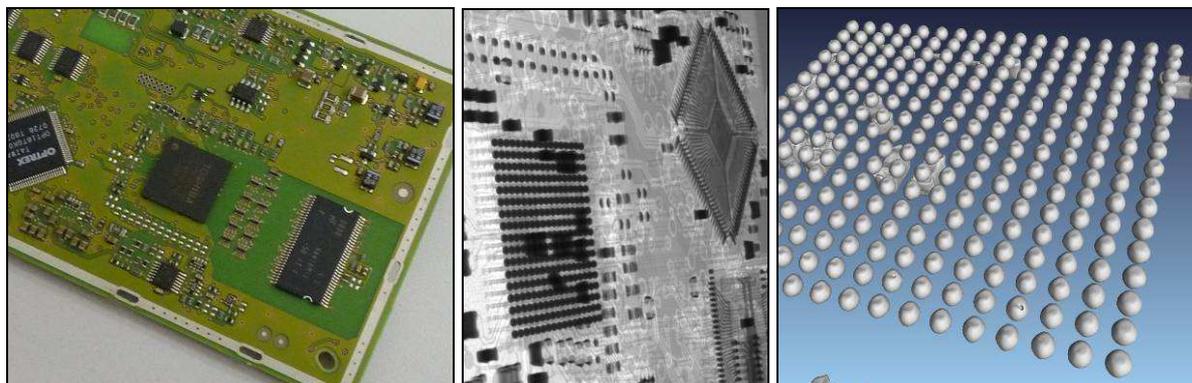


Figure 5. PCB a) real PCB b) x-ray picture, c) rendered point-cloud of solder

II. Conclusion

In this article, the possible ways of using the industrial computed tomography in the area of electrotechnics, electronics and mechatronics are being shown. Besides these spheres, its use is significant in the area of mechanical engineering and automobile industry with the possibility of precise measurement of length and angle dimensions, and deviations of shape and position. Every measurement described in this article was done using the tomograph Metrotom 1500, Carl Zeiss situated in the *Computed tomography technology centre* at the Technical University of Kosice. The maximum permissible error of this machine is $MPE = \pm (9 + L/50) \mu m$.

This article was elaborated with the help of Grant agency MŠ SR for VEGA projects 1/0022/10 “A contribution to the research of measuring strategy in coordinate measuring machines” and KEGA “Complex computed aided education of coordinate metrology for school and praxis”.

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