Industrial Computed Tomography in Biomedical Engineering

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Abstract. *Computed tomography scanners (or CT scanners) are very popular medical equipments for tens of years. Its invention initiated a revolution in diagnostic technology by allowing us to look inside a person and obtain a very clear anatomical image without violating the outer surface of his body, in other words, non-invasively [10]. Just few years ago this technology found way to the area of industrial applications. Presented paper describes metrological possibilities of industrial tomography in the area of biomedical engineering in order to hardware limitations and software functions.*

Keywords: industrial computed tomography, biomedical engineering, measurement

1. Introduction

More than one hundred years ago X-ray technology started its triumphal procession when Wilhelm Conrad Roentgen discovered a new kind of radiation in his laboratory in Wuerzburg, Germany in the year 1895. Up to this moment most of the developments on X-ray technologies and computer tomography have been focused on special medical applications. Another twenty years later computer tomography (CT) has become a powerful, well accepted tool in industrial applications as well. Today industrial CT is on its way to become a major tool of industrial quality control in high-tech branches, not only for material testing but for geometry analysis as well. Industrial CT uses a series of 2-dimensional (2 D) images taken at specific intervals around the entire sample. Basically any type of industrial CT system uses three principal components: an X-ray tube, an X-ray detector, and a rotational stage. Everything is enclosed within a radiation shielding steel/lead/steel cabinet. Micro computed tomography (micro-CT) is primarily the same as standard CT except it uses a micro focus tube instead of a traditional tube. A micro-CT scan yields resolutions in microns because the focal spot of a micro focus tube is only a few micrometers in size. For comparison, micro-CT resolution is about 100 times better than the best CT scan in the medical field.

2. Possibilities of industrial tomography

Metrotomography presented by Metrotom device uses X-ray technology based on a simple principle: an x-ray source illuminates an object with an electro-magnetic beam – the x-ray beams. The beams meet on a detector surface and are recorded in varying degrees of intensity depending on the thickness of the material and its absorption characteristics. The result is a two-dimensional gray-scale image. However, this image is only meaningful for visual inspection when shown as a cross section. Metrotom rotates the component 360° around its own axis, thus producing a 3D image of the interior of the part.

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. The main industrial tomography areas of the use are:

- testing: - quality of the connections in assemblies

- analysis of the porosity
- analysis of the defects
- inspection of the material

- measuring the dimensions of the inner and outer elements
- reverse engineering (obtaining the CAD model from the real part)
- comparing the nominal with actual geometry

3. Application in biomedicine

Technology center of computed tomography at Technical university of Kosice serves as support for many kind of researches. Biomedical research or research in prosthetics and orthotics are important supported areas. Tomography can be used for various evaluations. One of the most used is digitalization of very complicated shaped objects. In biomedical engineering there are many objects with so complex surfaces, that they are not measurable by any other methods of digitalization. Touching probes, lasers or optic scanners can not reach areas which are mostly hidden or unobtainable. With CT scanners we obtain 100% information about object shape. Because of that for example animal skull (fig. 1) can be digitized. VGStudio Max is software which allow extract STL model from surface points. STL is universal triangular model which can be imported to almost every CAD/CAE/FEM/RP software for further processing.

With CAD software it is possible to do parameterization or design a supplement for scanned object. In FEM (Finite element method) software the stress/strain analysis can be performed. STL model is ideal type of model for Rapid Prototyping. With 3D printer the plastic or metal copy of real object can be done. On the pictures bellow (fig. 1) can be seen original and printed copy of monkey skull. More about express creation of complex shaped object copy can be found in authors other publications [10].

X-ray is kind of radiation which can penetrate through objects. Because of that we have information not only about surface of object, but also about inner volume. After reconstruction of point cloud we can look inside the object by using virtual cross-sections without destroying of real object or separate materials with different density.

Fig. 1. STL model of monkey skull generated from point cloud (left) and copy of scull made with rapid prototyping technology compared to real scull (right)

In the figure 2 the separation of different plastics, composite materials and wood is shown. Prosthesis contains components which are not visible. On reconstructed point cloud we can set transparency for polyurethane and inner components appear in 3D rendered visualization.

Another research supported by CT technology at our laboratory was porosity analysis at two samples of human bones. The research was focused to compare amount of solid phase of two human demineralised bone matrices, where one of them was cultivated with mesenchymal stem cells (MSC) for two weeks.

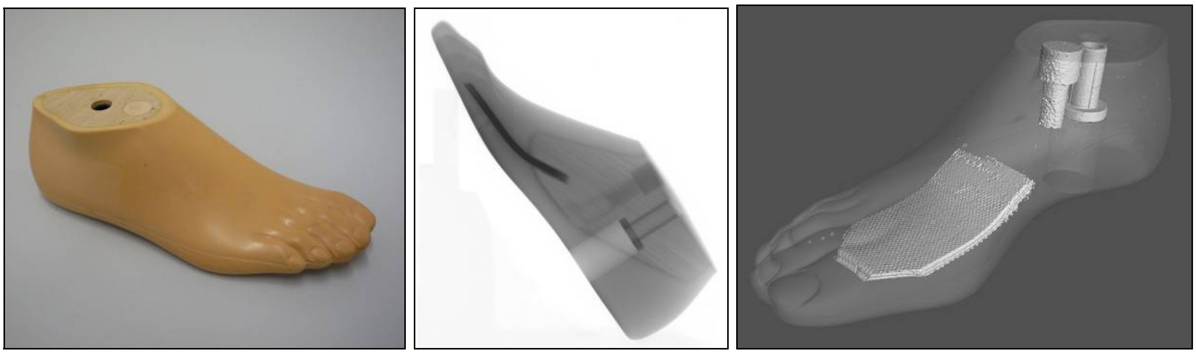

Fig. 2. Prosthesis (left), its x-ray image in selected position (middle) and rendered point cloud with predetermined transparency of PUR material (right)

After cultivation the amount of solid phase increased rapidly and the results can be seen also on figure 3. Porosity of selected regions of interests have been calculated and compared. Results of research can be found in authors' publication [5].

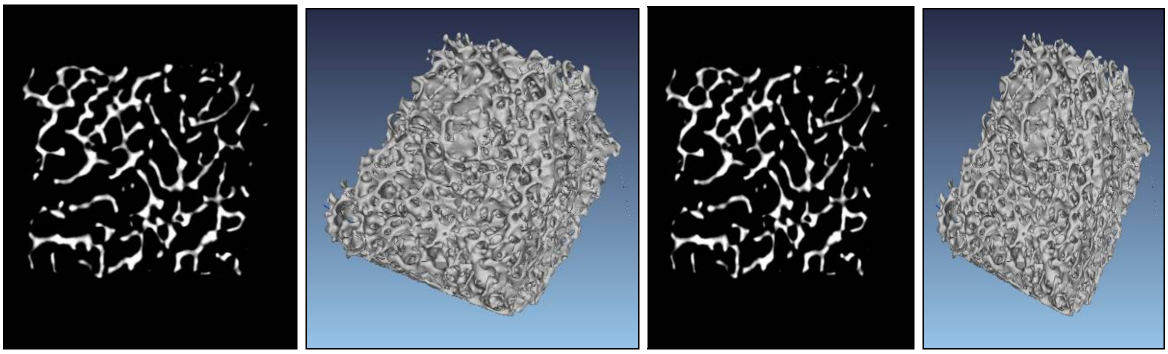

Fig. 3. Demineralised human bone matrix without hMSCs (left) and demineralised human bone matrix with hMSCs after two weeks of cultivation (right) in cross-section views and 3d rendered views

Industrial tomography is a branch of technology which gives not only advantages of nondestructive testing and viewing of inner structure, but the reconstructed data are so accurate, that this technology can be used for very precise geometrical measurements. Also in biomedical applications it is necessary to measure characteristics, which are difficultly measurable by any other technology without destruction. Spherical form of used acetabular component was measured with Calypso software. This metrological software is used for almost all coordinate measuring machines from Carl Zeiss. With Calypso we can evaluate characteristics of objects and make a protocols or graphical presentations of results. Graphical interpretation of form deviations at acetabular component in magnification are presented on figure 4. Deviations have been filtered to eliminate scratches on the spherical surface.

Quality of reconstructed point cloud and accuracy of measured data markedly depends on density and cumulative wall thickness of scanned object. Because of that material with lower density are more suitable for scanning than denser materials. Titanium, in comparison with other metals (steel, copper, etc.), is a metal with relatively low density and because of that small components made from titanium are measurable without restrictions.

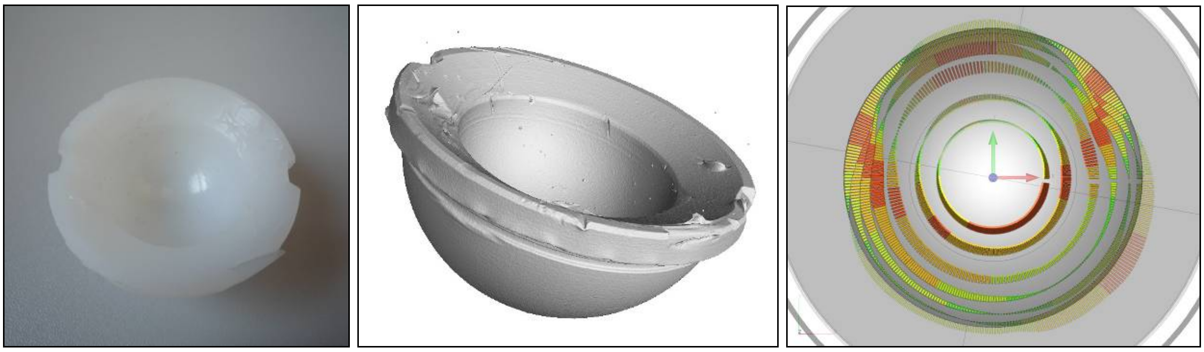

Fig. 4. Used acetabular component (left), rendered point cloud (middle) and form deviations on spherical surface (right)

One of the latest researches supported by our laboratory is digitalization of titanium dental implants. Analyses of material homogeneity, porosity, assembly quality and geometry have been performed on four different implants (fig. 5).

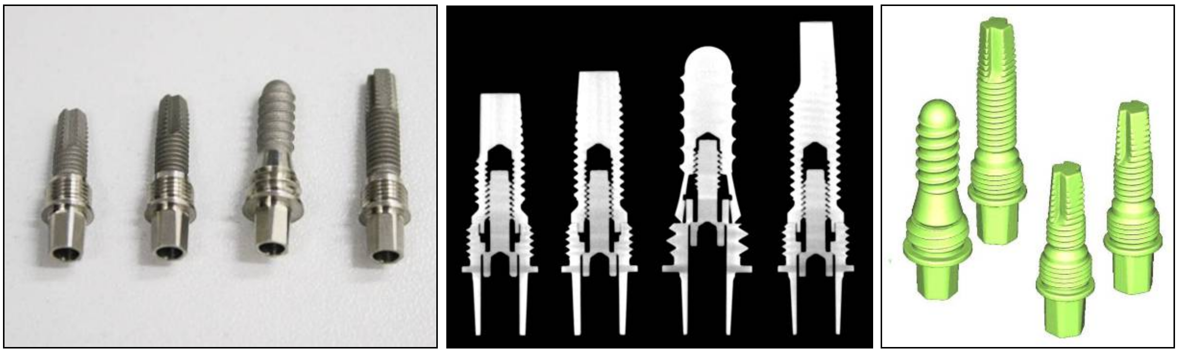

Fig. 5. Four dental implants (left), cross-section of point-cloud (middle) and STL files imported to metrology software Calypso prepared for measurement

4. Conclusions

The paper deals with relatively new technology - industrial tomography - and application oriented to biomedical engineering. This technology with its advantages can increase quality of biomedical products. A possibility of analysis of osteosynthetic junctions, analysis of total replacements in order to endoprosthesis release and analysis of biomechanical properties of materials (monitoring of cavities, composities research, etc.), analysis of junction in medical devices, 3D modeling byreverse engineering and following rapid manufacturing are just few of applications.

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