

# NEWSLETTER SPRING 2019

Dear Readers,

in the new issue of our laboratory newsletter you will read about our new cooperation with Xray-Lab (Germany) and about testing of a special holder for simultaneous measurement of multiple samples in our laboratory. Furthermore, we will introduce you to various approaches of calculating porosity. Our results will be supported by showing you concrete examples: the products of metallic 3D printing which were analyzed in the framework of inter-laboratory comparison.

Enjoy the reading!

**Tomáš Zikmund**  
Head of the laboratory

# NEW POSSIBILITIES OF THE CT ANALYSIS USE

## POLYCT TESTING

In the previous months, our laboratory had an opportunity to test a novel tool developed by Xray-lab & Fraunhofer Development center for X-ray Technology (EZRT). This product serves as additional equipment to the standard CT system. It aims to reduce the required scanning time by a factor of three.

The main principle of the tool dwells in the scanning of three samples in one measuring procedure. In the case of standard CT, this would lead to the creation of various types of image artefacts due to samples' overlapping at particular angles of rotation during scanning. However, in this case, the rotational movement of one stage is mechanically transferred into three individual rotational units on which the samples are mounted (<https://polyct.com>). The only condition for the installation of the tool is that it must be mounted and fixed into the chuck and the body of the tool must be fixed via magnetic base (Fig. 1).

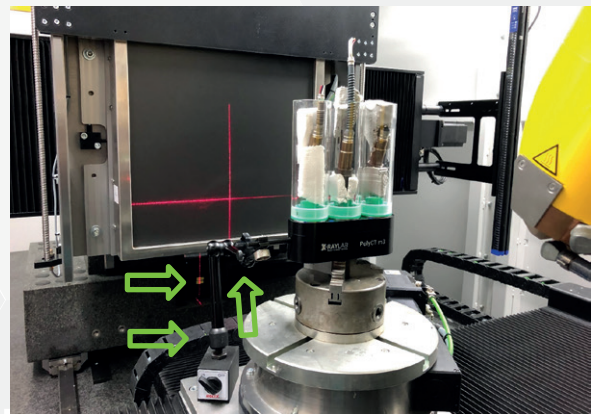


Fig. 1: The PolyCT tool with three sensors placed in plastic tubes. The handle connecting the magnetic base and the body of the holder is highlighted with arrows.

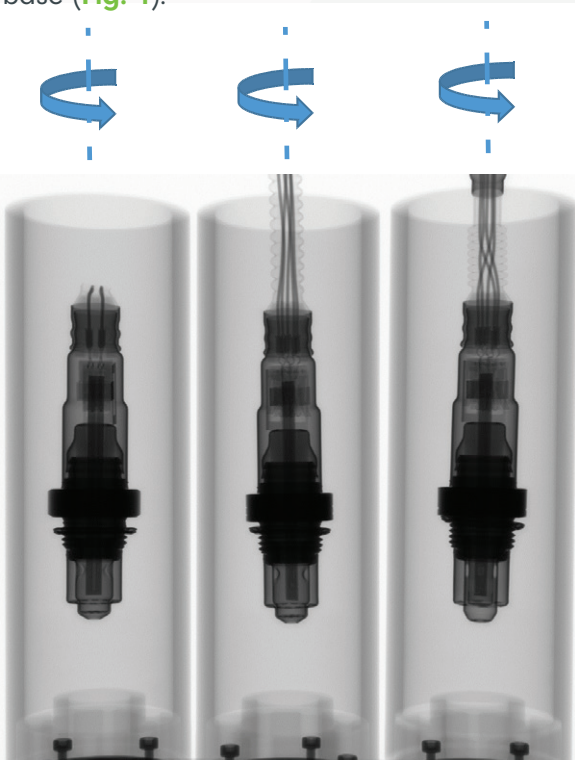


Fig. 2: RTG projection of three sensors placed in PolyCT tool on GE phoenix v|tome|x L240.

Thanks to this, the tool may be installed in any kind of standard industrial CT stations. The manufacturer provides users with their custom made reconstruction software. When used with the high-performance graphics cards, the required reconstruction time can be shortened to a few minutes. The whole procedure has been tested on a sample of three sensors (Fig. 2, 3).

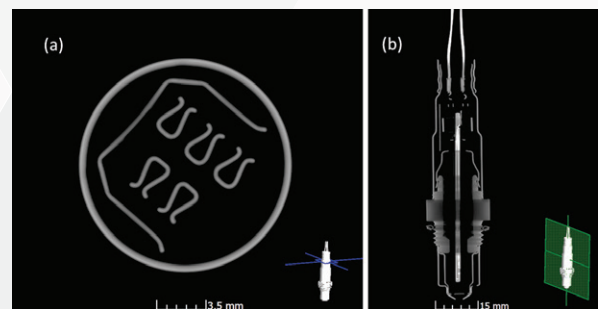


Fig. 3: CT slices of one selected sensor. Position of the slice is indicated in the 3D model.



## 3D PRINTING OF MOUSE EMBRYO

In our laboratory we try to make our results as clear as possible for our cooperators – developmental biologists. For this reason, we have recently prepared and realized 3D printing of whole mouse embryos in cooperation with the Department of Reverse Engineering and Additive Technologies, Faculty of Mechanical Engineering at the Brno University of Technology. Mouse embryos were analyzed using microCT and from the CT data the 3D model was created and printed (Fig. 4). The 3D model of embryo is made of transparent material and the spine is filled with blue ink. Transparency of the 3D model allows to observe the position of the spine against the body of the embryo. For a more detailed study of morphology and comparison of a healthy one with a mutant, the spine was printed separately in a larger size (Fig. 5). The differences of both 3D models were presented at the conference Visegrad Group Society for Developmental Biology: Inaugural Meeting (<https://webcentrum.muni.cz/visegrad2018>).

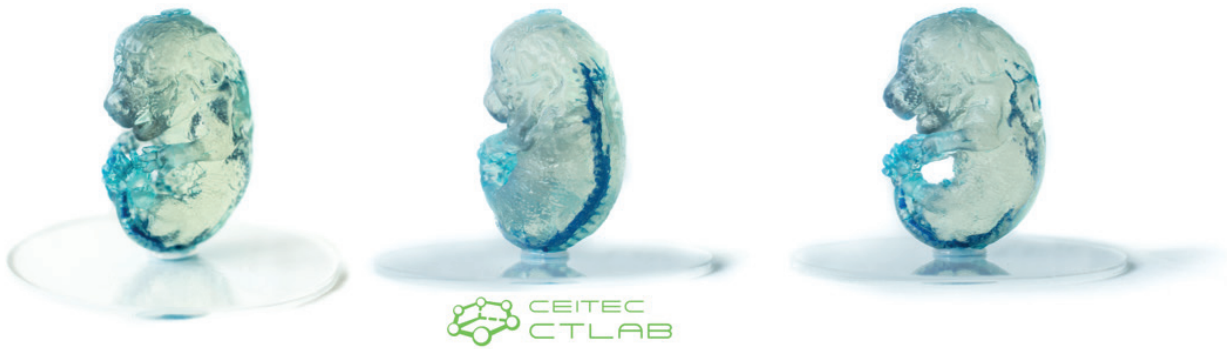


Fig. 4: View of 3D model of mouse embryo, the size of the model is approximately 15 cm.



Fig. 5: View of 3D models of spines: healthy and genetically modified mouse embryo, the size of the model is approximately 25 cm.

## POROSITY

Determination of porosity is one of the most significant demands in X-ray computed tomography. Porosity  $P$  is defined in quantitative terms as a ratio of pore volume  $V_p$  and total volume of a sample including pores  $V$ :

$$P [\%] = V_p/V * 100 \%$$

To determine the total sample volume, the critical point is the determination of the original surface so that it does not include the pores connected to the outer space (Fig. 6a). This is achieved either by more advanced image processing methods or by implementing the analysis on an inscribed area of defined shape. The segmentation of air itself is then performed most often by thresholding, which assigns voxels to the material or background category based on the intensity values.

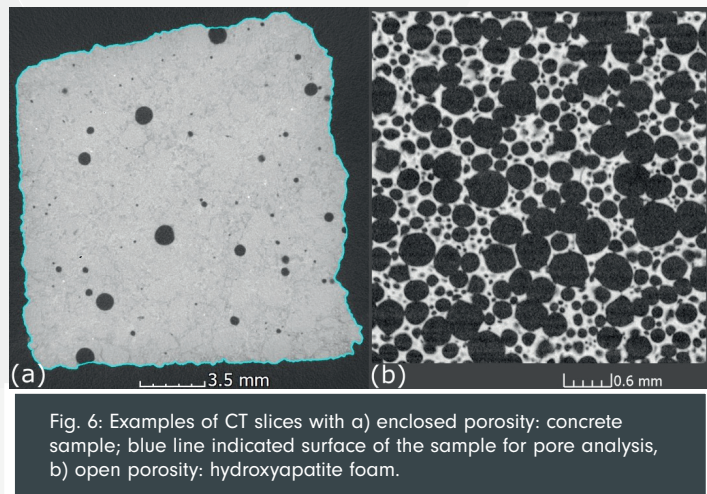


Fig. 6: Examples of CT slices with a) enclosed porosity: concrete sample; blue line indicated surface of the sample for pore analysis, b) open porosity: hydroxyapatite foam.

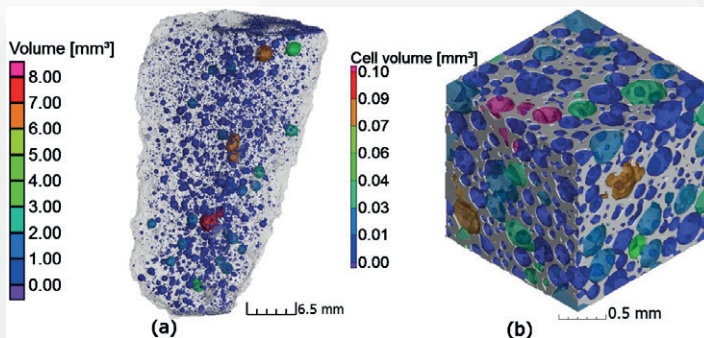


Fig. 7: Porosity analysis of sample with a) enclosed porosity: concrete sample; b) open porosity: hydroxyapatite foam. Individual pores are colour-coded according to their volume.

There are two basic categories of porosity, based on their morphology character.

The first one is the enclosed porosity in which each pore forms a separate volume (Fig. 6a) surrounded by the material. In industry, the typical examples are metal castings, plastic mouldings, or 3D printing products.

The pores disrupt the homogeneity of the inner structure and reduce the original mechanical properties of the part. Manufacturers put a lot of effort to minimise it. The  $P$  value, in this case, becomes an indicator of the product quality and it is supplemented by the information about pore size (maximum size, the largest linear pore size), their distribution in the sample, and their distance to the sample surface (Fig. 7a).

The second type is the open porosity (**Fig. 6b**) where the pores are interconnected. The structure of the sample thus creates a unique network of thin walls that provides the components with low weight, good insulation properties and impact resistance. Typical examples are aluminium foams, foam glass or biomaterials for regenerative purposes. In this case, the porosity number rather defines a given internal structure than the product quality. In such a complex structure, only the porosity or pore number (**Fig. 7b**) is insufficient to characterise the structure, and therefore the pore shape (sphericity), pore connectivity, contact area between adjacent pores, and average wall thickness are also evaluated.

## PARTICIPATION

### ICT 2019 CONFERENCE, PADOVA (ITALY)

The iCT 2019 (9th International Conference on Industrial Computed Tomography) was held in the Italian city of Padova on 13th - 15th February, and was organised by the University of Padova and University of Applied Sciences Upper Austria. This year, our laboratory participated in this conference with 4 contributions concerning the field of developmental biology, development of nano CT device and helical trajectory. Our contributions are available on our web: <http://ctlab.ceitec.cz/posters/>. Full text PDFs of our contributions are available here: [www.ndt.net/iCT2019](http://www.ndt.net/iCT2019). The conference programme was divided into three days and among covered areas there were new methods and optimisation, algorithms and tomographic reconstruction, metrology, non-destructive testing, materials characterisation and manufacturing. During the conference, latest products of tomographic equipment or software were presented, among the presenting companies were e.g. Volume Graphics, Bruker, Avizo, Thermofisher Scientific, Tescan, Zeiss and others. The anniversary tenth year of this conference will be held in the Austrian city of Wels next year.

## NEW PUBLICATIONS

### OUR NEW ARTICLE IN SCIENTIFIC REPORTS

It is generally known that if the salamander loses its limb, it will be renewed. The regeneration capability of salamanders and other amphibians was described long time ago. However, what is not known is how this mechanism occurs in nature. An important step in clarifying the regeneration mechanism is to observe the geometry of skeletal and muscle structures during the growth and development of salamander.

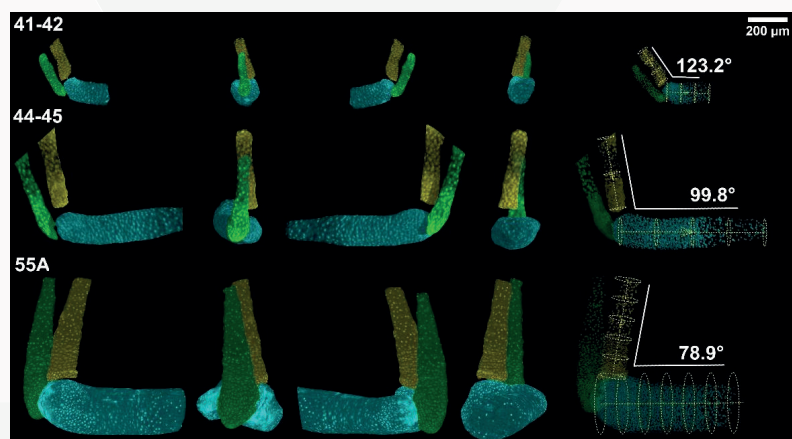


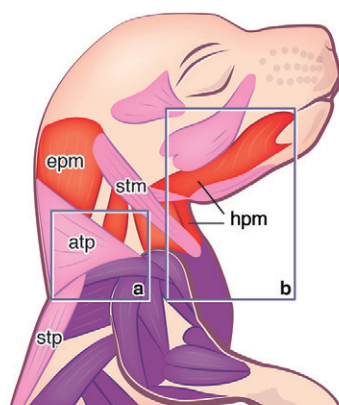
Fig. 8: Development of cartilage of the joint for three different developmental stages. The angle between ulna and humerus is decreasing with increasing developmental stage.

Markéta Tesařová, PhD student from our Laboratory of X-ray micro and nano Computed Tomography at CEITEC BUT, has been working on this topic together with biologists from Karolinska Institutet for more than two years.

Her research has been focused on the visualization, quantification and analysis of different structures of salamander with cellular resolution in three-dimensions. The results of her investigation were recently published in prestigious Scientific Reports journal (Nature Publishing Group, IF 4.6). In this work, synchrotron X-ray computed microtomography was used for a quantitative analysis of the 3D-cell distribution in tissues of a developing salamander's (*Pleurodeles waltl*) limb – a key model organism for vertebrate regeneration studies. Using the tomographic approach, the cell polarity was studied in relation to the developing joints of the salamander model. A visualization of these structures in 3D is the first step to a chance to cure injuries or illnesses in which defined cell type dies in the body.

The full paper is available here: <https://www.nature.com/articles/s41598-018-32459-2#article-info>.

## SCIENTISTS FROM INSTITUTE PASTEUR AND CEITEC BUT REVEALED MORPHOGENETIC SIGNATURES DEFINING MAMMALIAN NECK MUSCLES



- Branchiomic muscles including cucullaris muscles
- Epaxial and hypaxial neck muscles
- Trunk and limb muscles
- NC-derived connective tissue and skeletal components
- LPM-derived connective tissue and skeletal components
- No NC contribution to connective tissue and shoulder

Fig. 9: Model for musculoskeletal and connective tissue relationships during murine neck development

Due to the complex morphogenesis, the development of neck muscles and connective tissues at vertebrates is still poorly defined. Biologists from Institut Pasteur together with scientists from our laboratory have been working on this topic for the last three years. They were using a combination of complementary genetically modified mice and 3D analysis by X-ray computed tomography that identified muscles in the context of their bone attachments. They provided a detailed map of neck tissue morphogenesis and revealed some unexpected features regarding the muscle and connective tissue network. The results of this study were published in the eLife journal. Besides the unveiling of the role of particular mesodermal origins, the publication contains interactive 3D PDF files of examined samples. These interactive documents allow readers to understand the complexity of muscles development in a user-friendly way.

The whole article is available here: <https://elifesciences.org/articles/40179>



## PARTICIPATION IN THE INTER-LABORATORY COMPARISON OF POROSITY DETERMINATION USING MICROCT

The porosity in microCT scans depends primarily on the instrument setup as well as on the operator's experience in data processing. Although the standards for calculating porosity are being developed, currently there is no universal procedure for tomographic data processing. The problematic part of the calculation is the segmentation of pores in the image, which is complicated due to tomographic artifacts. For this reason, there is an inter-laboratory comparison in the framework of the research in which our laboratory participated. The international inter-laboratory testing for microCT determination of porosity is organized by Stellenbosch University in South Africa. For the purpose of this study, a 10 mm metal cube was created using LPFB (Laser Powder Bed Fusion) technology. LPFB is a 3D printing technology that uses sintering of a metal powder layer with a powerful laser.

The tomographic measurement of the cube was performed with the specified measurement parameters and the data was obtained with 15  $\mu\text{m}$  voxel resolution.

A uniform procedure based on thresholding was applied to determine the porosity. The threshold value was selected by the operator based on a visual assessment (Fig. 10c-d). The porosity of the analysed cube is 0.02%. The volume of majority of pores is less than 0.08  $\text{mm}^3$  and most of them are distributed below the surface (Figure 10f).

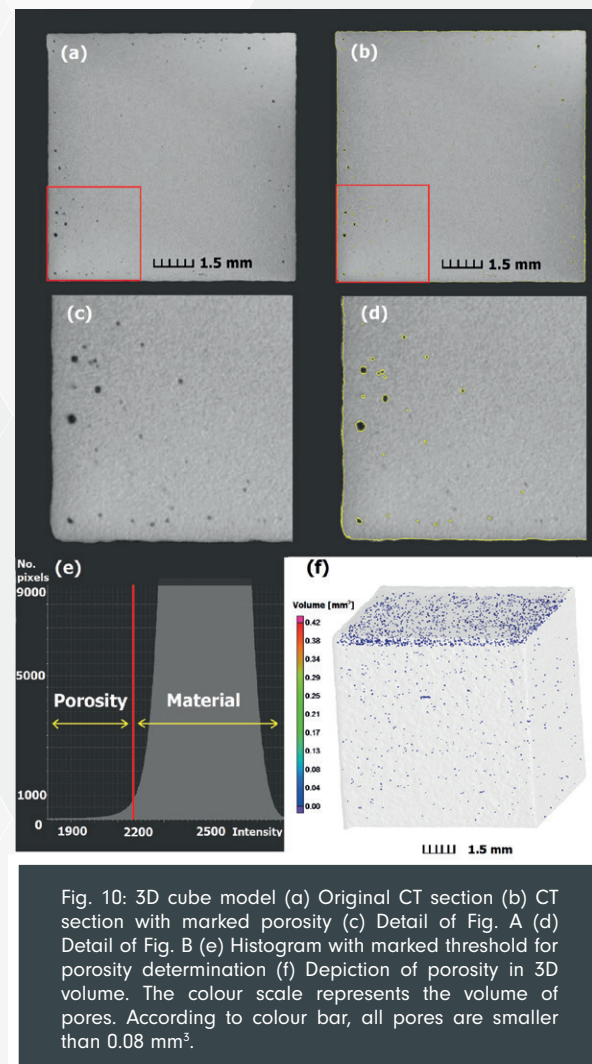


Fig. 10: 3D cube model (a) Original CT section (b) CT section with marked porosity (c) Detail of Fig. A (d) Detail of Fig. B (e) Histogram with marked threshold for porosity determination (f) Depiction of porosity in 3D volume. The colour scale represents the volume of pores. According to colour bar, all pores are smaller than 0.08  $\text{mm}^3$ .

## GE WORKSHOP

On 28 - 29 May 2019, our laboratory organized the first **GE workshop for non-destructive testing in the automotive industry**. This was a unique event in the Czech Republic. By organizing this event, GE followed up on previous years' meetings from Cincinnati (Ohio, USA) 2018 and Albany (New York, USA) 2017. The aim of the seminar was to present to industry experts some recent technologies from the manufacturers' perspective, to share the experience of non-destructive testing, and to define development requirements in the automotive industry. There were 52 participants from more than 20 Czech and foreign companies. Among the speakers were the representatives of CzechInvest, Volume Graphics (Germany), the Czech Metrology Institute and Synchrotron Elettra (Italy).

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