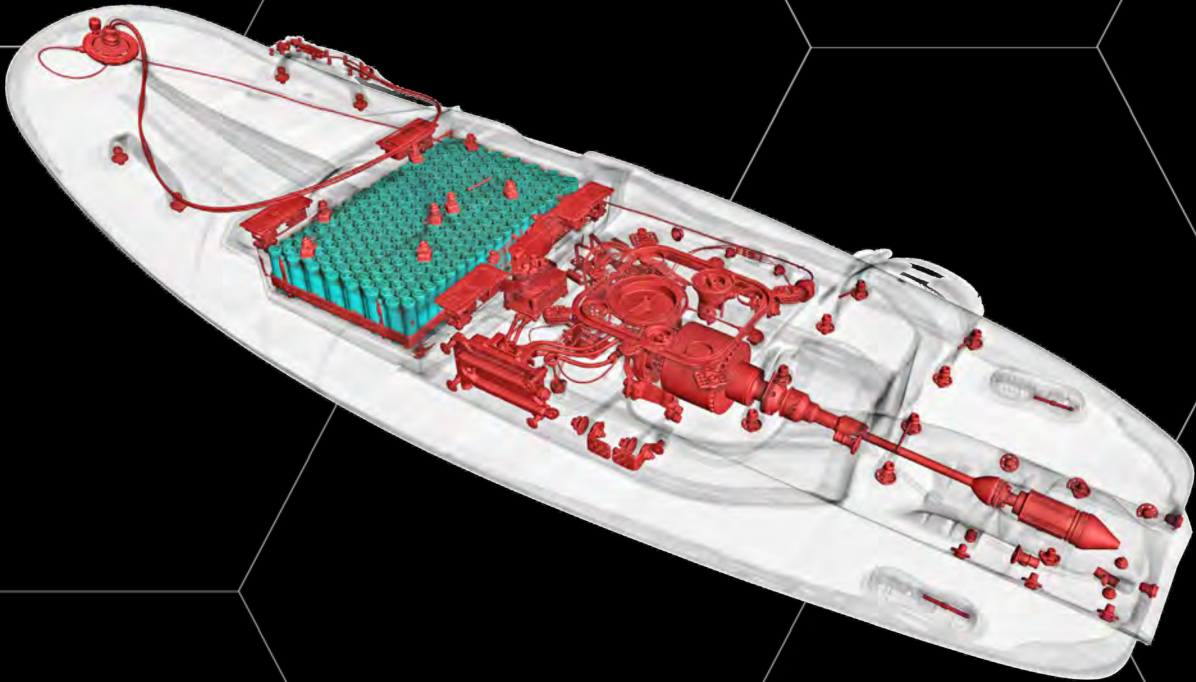
CEITEC CTLAB

BRNO UNIVERSITY OF TECHNOLOGY



CT analysis of the two-meter Jetsurf on page 2.

NEWSLETTER SPRING 2023

It is a pleasure for me to present you with a new issue of the newsletter of our Laboratory of X-ray Micro and Nano-Computed Tomography at CEITEC BUT. You can read about some of our recent explorations, including testing a unique two-meter surfboard powered by an electric motor. We will explain to you what LINAC CT means and show what the interface between two parts of a sample additively manufactured from different metals looks like.

Enjoy reading!

Tomáš Zikmund
Head of the laboratory

JETSURF TESTING ON LINAC CT

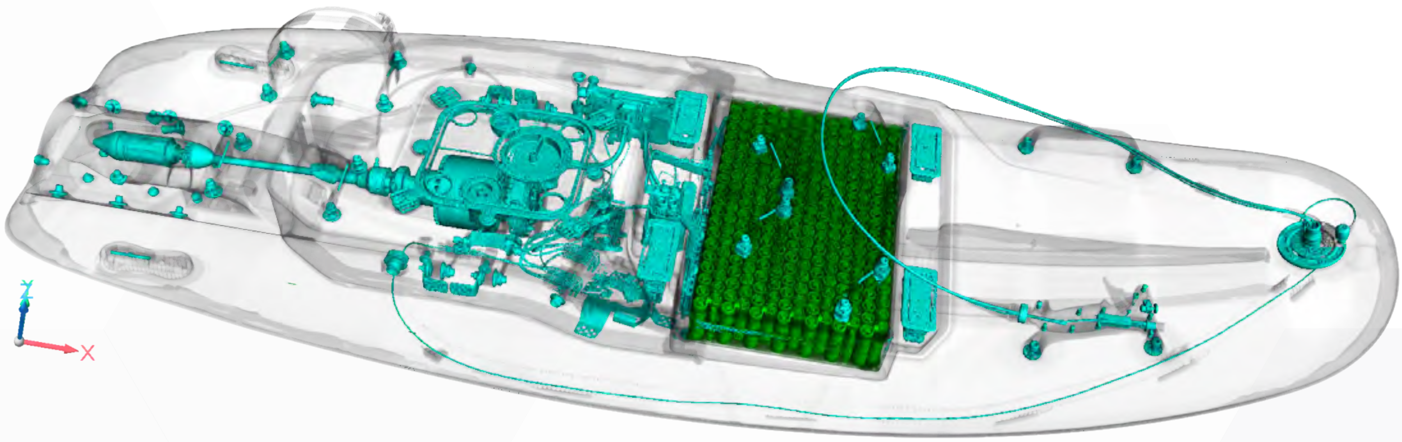
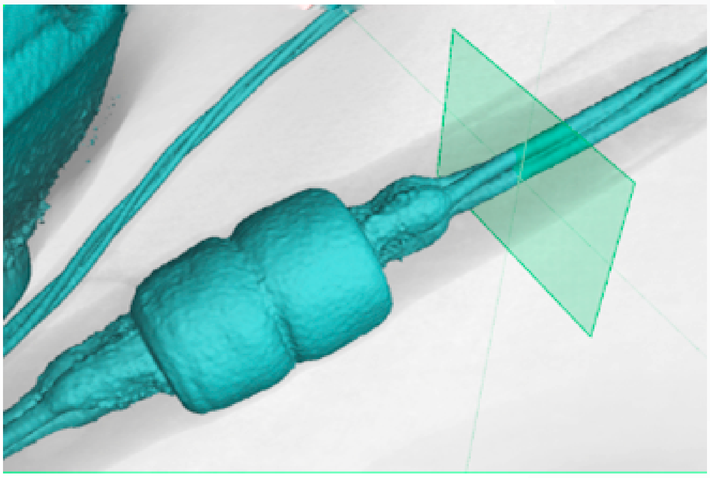


Fig. 1: 3D render of scanned Jetsurf.

We tested one of the most advanced CT Technologies!
In collaboration with Waygate Technologies, a global manufacturer of CT equipment, we utilized their special industrial CT scanner based on a 9MeV linear accelerator (LINAC CT) to scan the entire Jetsurf, two-meter-long surfboard that weighs over 50kg and is powered by an electric motor. The surfboard, which contains various absorbent materials, was scanned in multiple sections for approximately 30 hours. From the measurements, we obtained highly detailed data with a voxel resolution of 150µm and a size of around 250GB. The level of detail obtained by this scan can be demonstrated by the clear visualisation of three copper wires, each with a diameter of 0.5mm, that are part of the control cable for the standing rider (Fig. 2).

This advanced technology opens the door to non-destructive testing of large samples and complex multi-material assemblies, including those with high-alloy steels that cannot be inspected using conventional micro tomography. The power of this technology can be viewed in the battery cross-section, which shows individual cylindrical cells with no metallic or scattering artifacts present (Fig. 4). Even though high-energy X-rays were used, lightweight materials such as carbon bodies or polymers displayed excellent contrast (see Fig. 3).



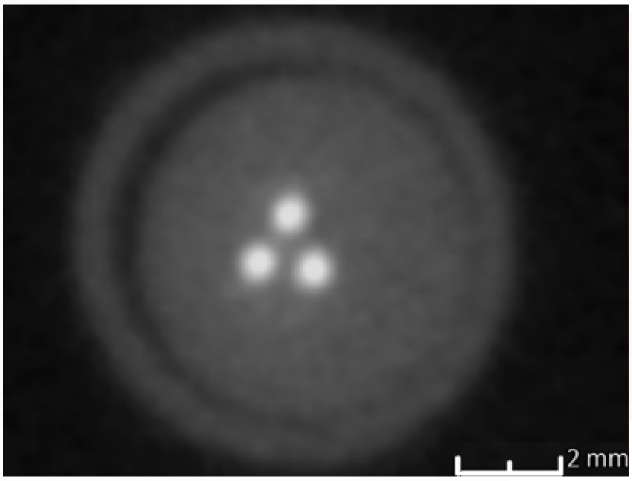


Fig. 2: The green reference plane on the left shows the position of the selected area of transversal tomographic cross--section containing copper wires.

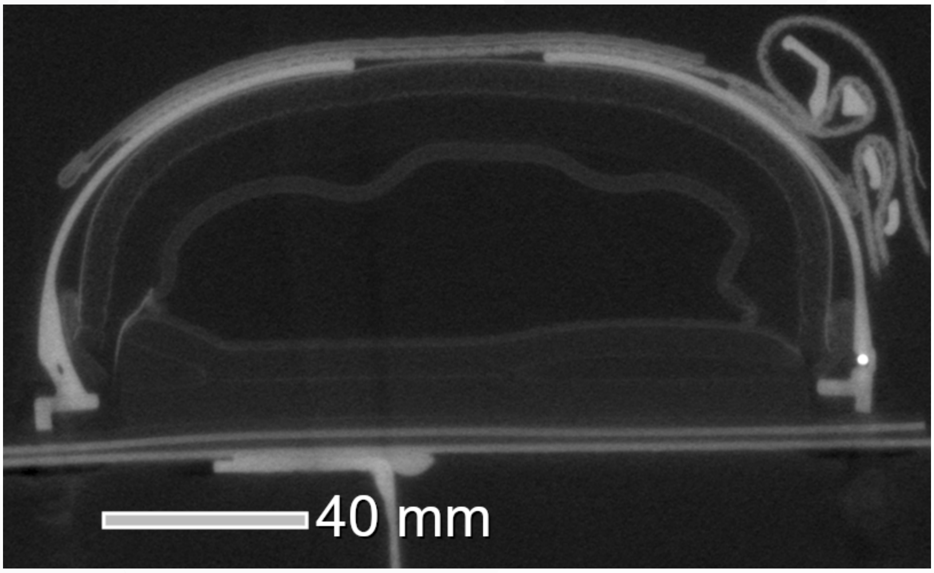


Fig. 3: Tomographic cross-section of the binding for the foot holding the rider connected to the surfboard. The bottom part shows the carbon body of the surfboard with a plastic buckle, velcro, and foam padding.

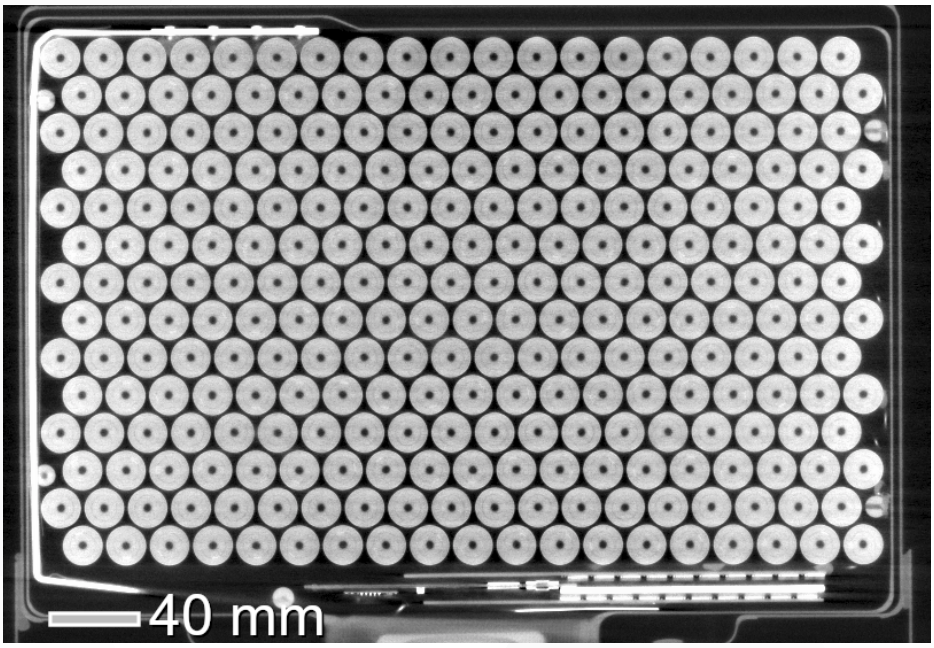


Fig. 4: Tomographic cross-section of the battery containing 266 18mm-diameter Li-ion cylindrical cells.

This test measurement is a part of the preparatory phase for the LINACTON project, which aims to bring high-energy CT to the Czech Republic and establish this technology for industry and also for research.

ANALYSIS OF A UNIQUE TEXTILE WITH CITYZEN® TECHNOLOGY

The production of cotton textiles is an old craft, which, however, has changed practically beyond recognition since the original production processes.Thanks to technological advances, it is now possible to create textiles with very precisely defined properties. During production, the key to success is very frequent quality control of the knitted fabric. Today's CT technology enables submicron measurements, which are a critical point in detection properties of the textile and control of its bonds. Thanks to 3D data, we obtain unique information about the tested material, whereas these measurements are becoming more popular in the textile industry.

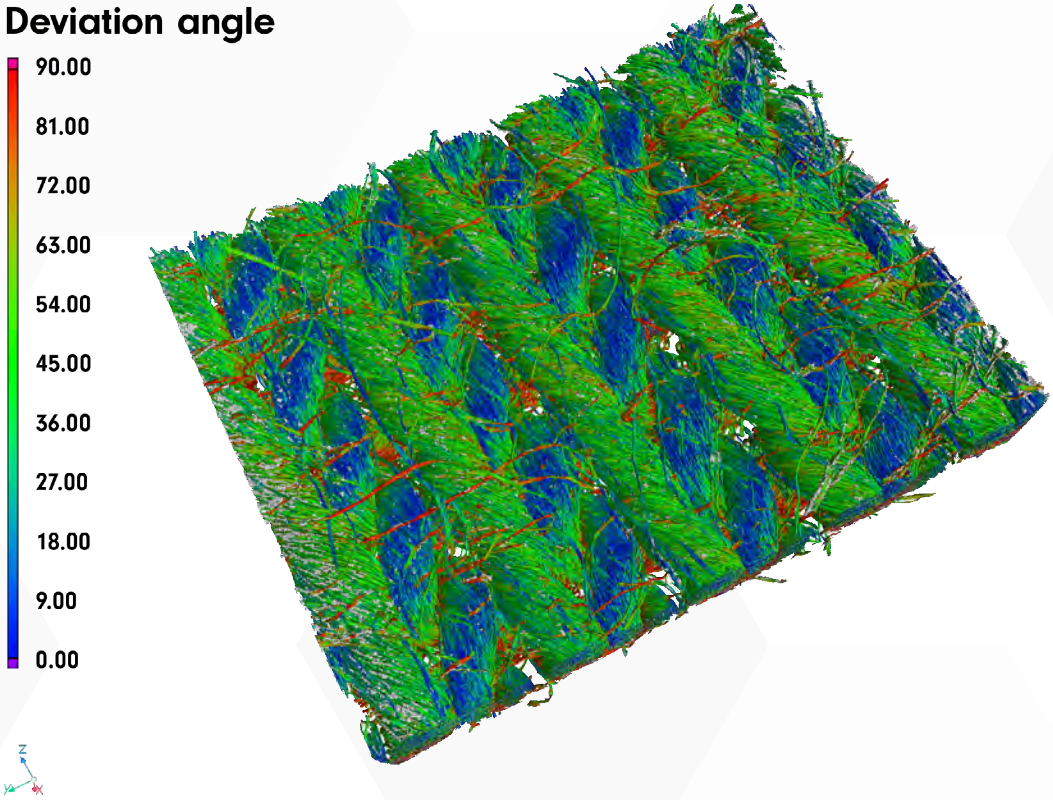


Fig. 5: Color-illustrated analysis of fiber orientation in a 3D textile model.

For CT analysis, we have chosen the unique CityZen® cotton knits, which are popular due to their properties. The technology itself is a very complex process, where individual steps are qualitatively controlled. Drying temperature, fixation, product pH and speed are the limiting parameters for a positive result. Thanks to these processes sweat is not visible on the fabric during normal wear or during sports. The facing outer layer is extra repellent to dirt and liquids. The layer touching the body is absorbent and absorbs away the moisture caused by it physical activity.

Long staple cotton (20 tex) is used in these knitwear. The high quality of the data enables to study the complex morphology around bonds. Fig. 5 shows the single-faced Single Jersey weave and interlacing yarn in this weave. Thanks to the properties of the knitted fabric, moisture is released at the bonding points and sweat evaporation. By applying CityZen® technology, there are no negative changes in the bonding points. This means that the transport of sweat and its evaporation is not prohibited.

EXPERIMENTAL METAL ALLOY COMPOSITES IN ADDITIVE MANUFACTURING

Like other forms of 3D printing, the additive manufacturing method of Selective Laser Melting (SLM) makes it possible to create intricate parts with unique shapes, which would be impossible to manufacture using common subtractive approaches. What sets SLM apart from other techniques is its usage of metal as the printing material. This makes it possible to print parts with excellent physical properties such as conductivity, strength, or toughness. Researchers from the Institute of Machine and Industrial Design at the Brno University of Technology are currently working on eliminating one of the few limits of this fairly young manufacturing method: the difficulty of combining multiple alloys in a single print. When the printing process is not optimal, the interface between layers of different alloys can be brittle and prone to delamination.

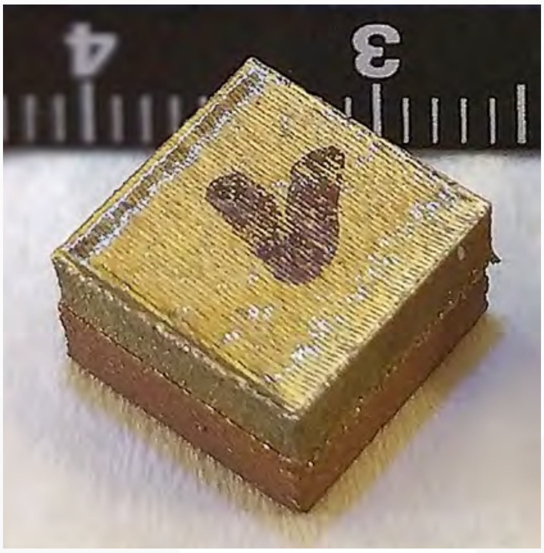


Fig. 6: Printed part.

Our laboratory had the opportunity to analyze two test prints made of tough and hard "maraging" steel and a hard copper alloy with outstanding thermal conductivity. The combination of these materials is suitable for constructing parts of combustion chambers in rocket engines, where the inner steel layer can endure the high temperatures and the outer copper layer efficiently cools the chamber by conducting heat away.

CT measurements of these prints let us evaluate the entire interface between the two alloys without breaking their integrity. In one of the parts, we were able to observe delamination and visualize its changing depth. In the second part, we examined the distribution of pores, which is variable between both materials (porosity is roughly 2.5× greater for the copper alloy) as well as in different regions within each material. A high pore density can weaken the structure of the printed part and lead to its structural failure. These results and observations can help identify key characteristics of the printed material interfaces and refine the SLM manufacturing process.

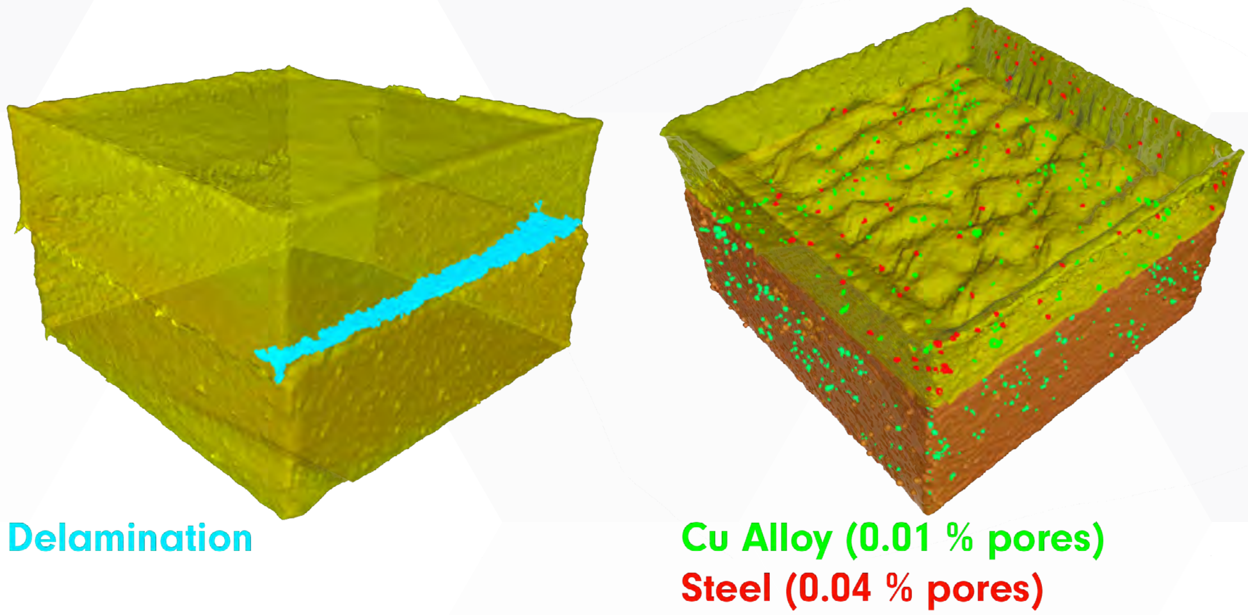


Fig. 7: Three-dimensional model of the delamination on the left, and an illustration of pores distributed mainly along the edges of the part on the right.

Author: Marek Zemek

LINEAR ACCELERATOR AS AN X-RAY SOURCE

The possibilities of 3D non-destructive analyses are expanding every year. The hardware of CT systems is being improved to achieve maximum resolution and scan larger or more dense samples. Individual CT systems are then differentiated by their type of specialization, which is indicated by the titles before the abbreviation CT (Fig. 8). Currently, scanning of large samples, or samples with high absorbance (radiodensity), is limited by the use of a conventional X-ray source. Conventional X-ray sources are constrained by the accelerating voltage to generate X-rays, which is typically around 450 KV, with a maximum of 600 kV. Scanning large or highly absorbing samples is thus problematic due to the insufficient amount of X-ray energy that would penetrate the material. The solution may be to use a linear accelerator (LINAC) as an X-ray source that can overcome this limit.

LINAC is a type of particle accelerator used to accelerate charged particles to very high energies. The charged particles are accelerated by an electrostatic field, which is made up of accelerating structures in a linear arrangement. The result is the generation of a high-energy, high-intensity radiation beam, which allows accurate and detailed imaging of the internal structures of samples, while maintaining equivalent spatial resolution to conventional CT machines (Fig. 8). LINAC devices can generate X-ray photons with energies exceeding 1 MeV, and for the purpose of computed tomography, typically 6 - 9 MeV.

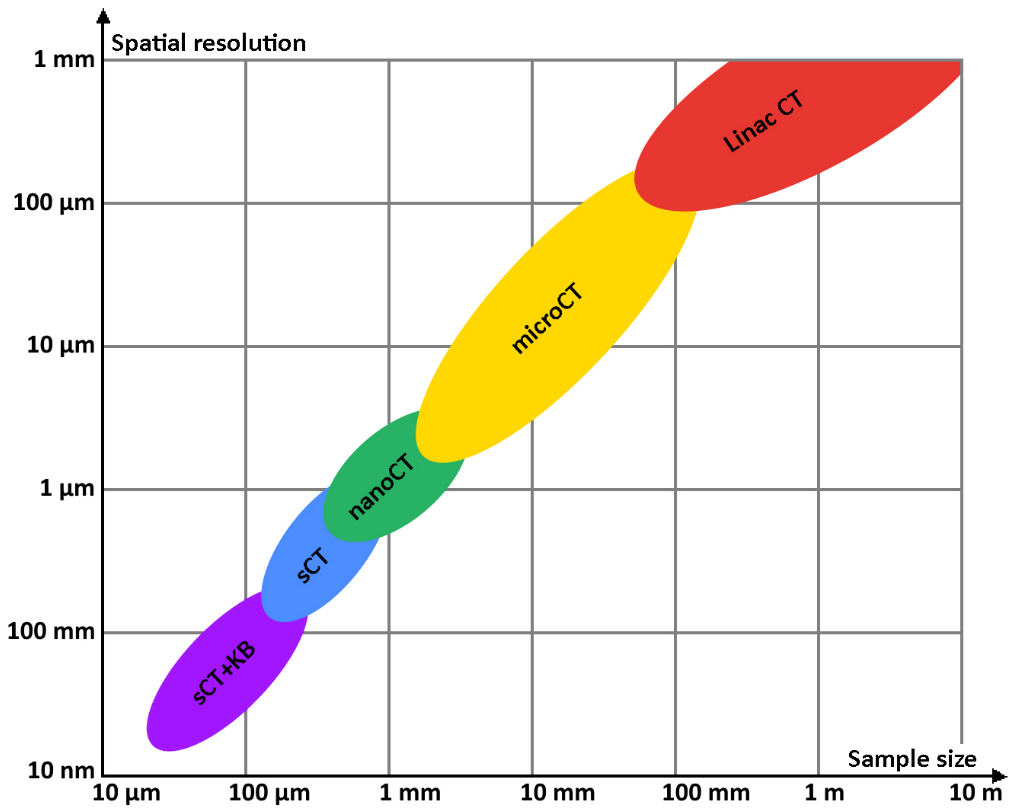


Fig. 8: Comparison of sample size and spatial resolution between instruments of different designs. Linac CT, micro CT, nano CT, synchrotron CT, synchrotron CT using Kirzpatrick-Baez optics.

LINAC is a fairly established device in medicine for radiotherapy treatment of cancer and is rarely used in industry. Due to increasing demands in the aerospace, defence and automotive industries, LINACs have also been developed and integrated into CT technology in recent years. Typical industrial applications include scanning of battery modules, high-alloy steel turbine blades, turbocharger housings, complete engine blocks, gearbox housings and large additive manufacturing parts.

Author: Jakub Lázňovský

INTERNSHIP AND COLLABORATION IN JAPAN

Our student Marek Zemek has attended a six-month internship as part of our long-term collaboration with the Rigaku Corporation, for which we operate as an application laboratory. The company headquarters is situated in the western suburbs of Tokyo, and it has been a developer of X-ray laboratory equipment for more than 70 years. Their products range from diffractometry to radiography, computed tomography, and spectroscopy. During his internship, Marek was dealing with the elimination of imaging artefacts which arise when scanning metal components. This work has the potential to improve the effectivity of tomography in the automotive industry and related fields. This internship also marked the end of a long break in regular internships of our students in Japan, which was caused by the coronavirus pandemic. Our laboratory is looking forward to further collaboration with Rigaku after Marek's return, both in terms of research and development of CT software and practical applications of our nano3DX CT system.

Author: Marek Zemek

OUR STUDENT WON THE WERNER VON SIEMENS AWARD

Ing. Markéta Tesařová, Ph.D, a recent graduate from our laboratory, was awarded the prestigious Werner von Siemens Award for third place in the Best Dissertation category for her dissertation entitled „Quantitative 3D characterization of biological structures by X-ray computed microtomography". At the same time, she also received the Award for the excellent quality of female scientific work. The results of this work have far-reaching significance not only for the professional community dealing with imaging methods, but also for biologists themselves. Thanks to these results, it has already been possible to elucidate, for example, the regenerative abilities of salamanders or the formation of cartilage and muscles in vertebrates.

Fig. 9: Ceremony of the Werner von Siemens awards, from the left the rector of CTU, doc. RNDr. Vojtěch Petráček, CSc.; CEO of the Siemens Group Ing. Eduard Palíšek, PhD., MBA; senior director of the section of higher education, science and research prof. PaedDr. Radka Wildová, CSc.; head of CTLAB doc. Ing. Tomáš Zikmund, Ph.D. and awarded Ing. Markéta Tesařová, Ph.D.

Author: Michaela Škaroupková

NEW SAMPLE PREPARATION TOOLKIT FOR SUBMICRON CT MEASUREMENTS

Submicron CT sample preparation is a very difficult discipline. In order to ensure that such small samples are not damaged and that the measurements are performed without complications, special tools are required. A collaboration between our CT laboratory and CactuX has resulted in the Essential Toolkit NANO, which solves this problem. Acquiring the right tools simplifies and streamlines the work of CT technicians. Because of its versatility and range of applications, the Essential Toolkit NANO is suitable for a wide range of applications across sample categories. It is useful in R&D, CT labs analyzing biological, geological, pharmaceutical samples and others, where each category of samples requires specific procedures and equipment. The kit contains 18 instruments for fixing, cutting, handling and clamping samples. The tools were determined based on years of experience. They are safe for use in the CT system, they do not affect the CT measurement process negatively, and allow optimization of the sample preparation process. To ensure that the sample is not affected or damaged by the air flow in the measuring chamber, we have also included kapton tubes in the kit. These isolate the sample from the chamber environment without significantly attenuating X-rays. The tools for fixation of the samples are represented by double-sided tape, dental wax, but also by an glue with higher viscosity and sufficient bond strength. The kit also includes rods and holders for sample holding, as well as a scalpel, scissors and other tools for sample preparation.

Fig. 10: Essential Toolkit NANO, a complete sample preparation toolkit for submicron CT measurements.

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