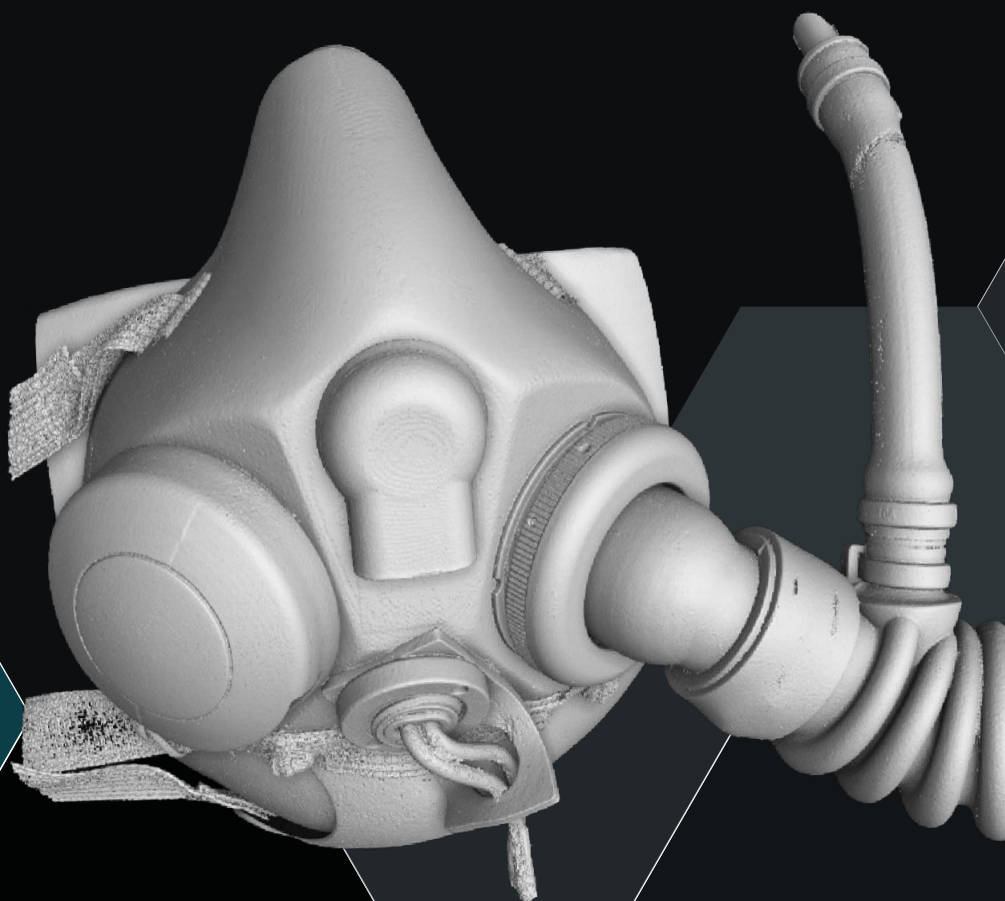




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NEWSLETTER AUTUMN 2026

It is my pleasure to present to you the latest issue of the newsletter of our X-ray Computed Micro- and Nanotomography Laboratory at CEITEC BUT. Here, you can read about some of our recent activities, including the non-destructive CT inspection of the aviation mask and a presentation of our laboratory's activities during a visit to Rigaku in Japan.

Enjoy reading!

Tomáš Zikmund
Head of the Laboratory

DIGITIZATION OF THE AVIATION MASK

The development of a new generation of integrated life support systems for combat aircraft crews represents a complex engineering challenge, where even minute geometric details determine crew safety and physiological well-being under extreme conditions. A key parameter in these systems is minimizing the dead space, where exhaled CO₂ accumulates and subsequently mixes into the inhaled oxygen mixture.

Our laboratory was actively involved in the detailed design analysis of a highly advanced oxygen mask designed specifically for a combat aircraft pilot, with the main goal of providing precise and detailed visualization of the mask's complex internal geometry. This is essential for the subsequent creation of a precise computational mesh for CFD (Computational Fluid Dynamics) simulations of breathing cycles, during which the quality and efficiency of the inhaled and exhaled gas mixture exchange are carefully monitored.

CT analysis enabled a non-destructive look into the assembled unit and precise capture of the positions of geometric details, including delicate membranes in their natural position, which cannot be captured by conventional methods. Among the main challenges of fixating a sample made of flexible materials is scanning it without affecting its natural shape. Similarly, it is undesirable to have any adhesive in contact with the sample, as it could be misidentified by software as part of the sample due to a similar density. The image below shows the actual fixation of the component in a position where metal clamping elements are located outside the scanned area.

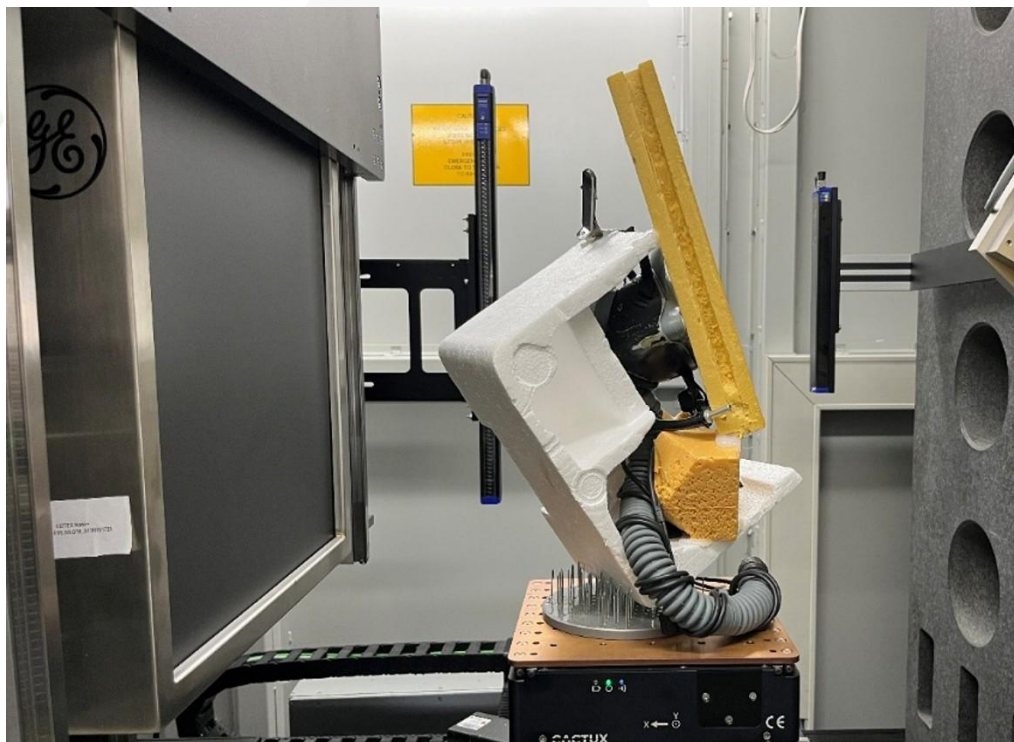


Figure 1: Photograph of the mask fixated for CT measurement. Metal buckles are located outside the measurement area, i.e., above and below the mask.

A common pitfall of a multi-material sample is the elimination of artifacts arising from the presence of metallic components-in this case, particularly valves-and the necessity for precise segmentation of materials with similar X-ray attenuation. In this case, we successfully differentiated 3 groups of materials with varying densities and exported their contours into STL format for subsequent, effective optimization of structural modifications aimed at eliminating dead space.

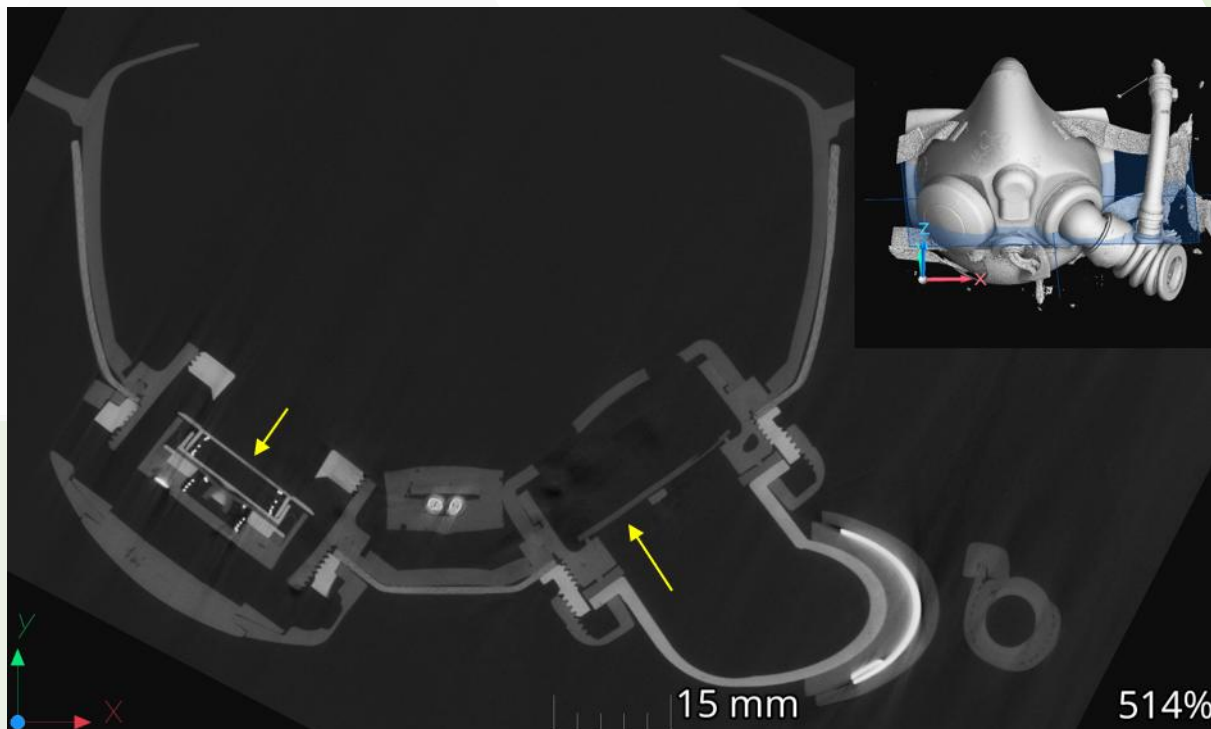


Figure 2: Tomographic cross-section of the intricate part of the mask. The position of the slice is shown in the 3D render. The arrows point to flexible membranes.

3D PRINTING OF PLASTICS FOR VACUUM APPLICATIONS

Today, 3D printing is finding applications not only in conventional manufacturing, but also in the demanding conditions of the space industry. However, using parts produced this way in a vacuum poses specific challenges. One of these is porosity-the presence of tiny air bubbles inside the printed part. In a vacuum, these can affect its mechanical properties and lead to outgassing of the trapped gas.

The objective of the experiment described below was to determine how 3D printing settings influence pore formation and whether a suitable printing strategy can be used to produce components suitable for vacuum conditions. Five test samples were prepared in the shape of a quarter gear with a radius of 25 mm (see Figure 3). The samples differed mainly in the pattern and density of the internal infill. The key question was whether the pores are located only in close proximity to the surface or also inside the component, and how their quantity correlates with the printing strategy used.



Figure 3: 3D printed sample in the shape of a quarter gear.

Using computer tomography, it was possible to look inside the printed samples without damaging them and to map their internal structure in detail. Pores were most frequently detected near the surface, as well as in more complex geometric sections and at the interface between the infill and perimeter walls. The location of these defects is precisely the key to better understanding the causes of their formation.

A comparison of individual samples also showed that the amount of pores can be significantly reduced by choosing an appropriate printing strategy. The results thus provided important feedback for optimizing 3D printing and demonstrated the potential of commercially available 3D printers for manufacturing components intended for vacuum applications.

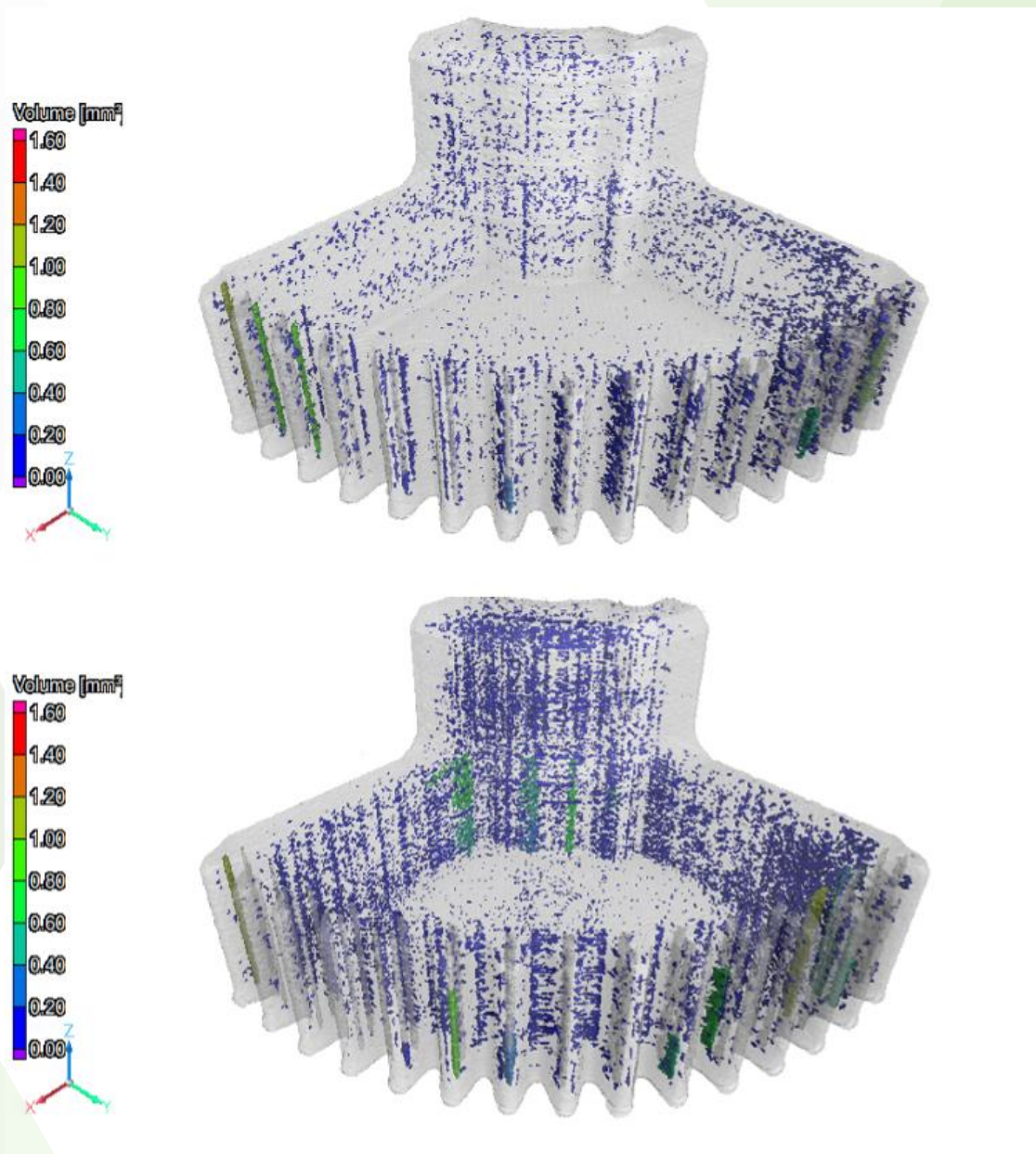


Figure 4: Visualization of porosity distribution in 3D. The pores are color-coded according to their volume.

INSPECTION OF A FORMULA CAR MIDWAY THROUGH THE RACING SEASON

During races, the racing single-seater withstands thousands of load cycles, vibrations, and impacts. When serious damage occurred to the wheel assembly of the student single-seater from the Brno-based TU Brno Racing team during a race at the Most circuit, it was crucial to determine not only the cause of the failure itself, but also the condition of other stressed components and whether the single-seater could safely continue competing with them.

However, a standard visual inspection is not enough in this case. Fatigue cracks or manufacturing defects can exist inside the components without being visible on their surface. This is precisely where we utilized the capability of analyzing the parts using X-ray computer micro-tomography, allowing this inspection to be performed in a non-destructive manner.

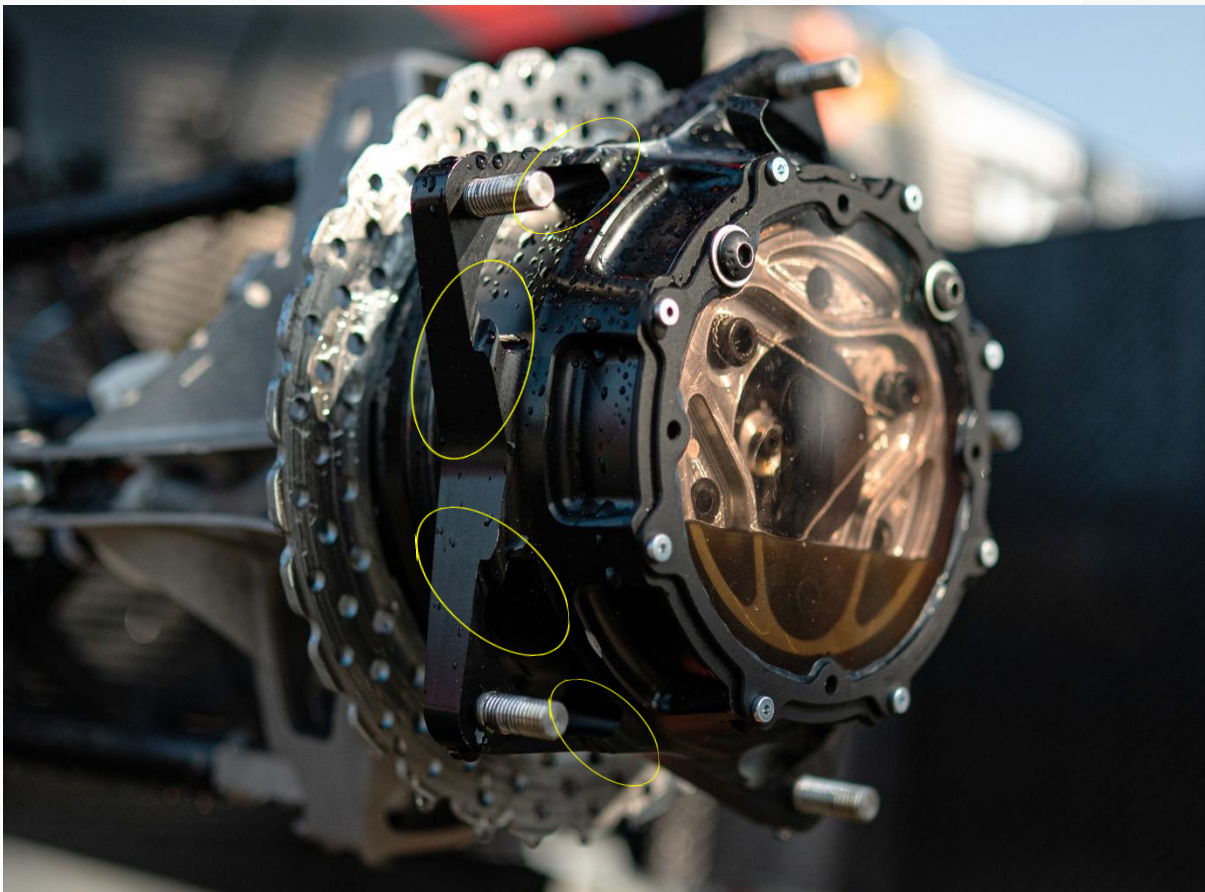


Figure 5: Photograph of the wheel assembly on the race car with the area marked for CT inspection.

The goal was to determine the initiation site of the fracture that triggered the damage to the entire wheel assembly, as well as to inspect all remaining components subjected to fatigue loading. For castings, the quantity, size, and distribution of manufacturing defects were monitored, whereas for suspension components, the quality of the bonded joints was evaluated. The most critical defects were discovered in the gearbox housing (the black component in Figure 5), where cracks were present even in previously undamaged wheel assemblies, prompting their replacement.

Non-destructive testing helped not only to prevent further damage to the single-seater during the race, but also provided valuable insight into the quality of individual manufacturing technologies, which will serve in future development. Tomography thus proved to be a highly useful tool for decision-making regarding the service life of critical components.

With the repaired car, the TU Brno Racing team secured two top-five finishes in the subsequent races in Croatia.

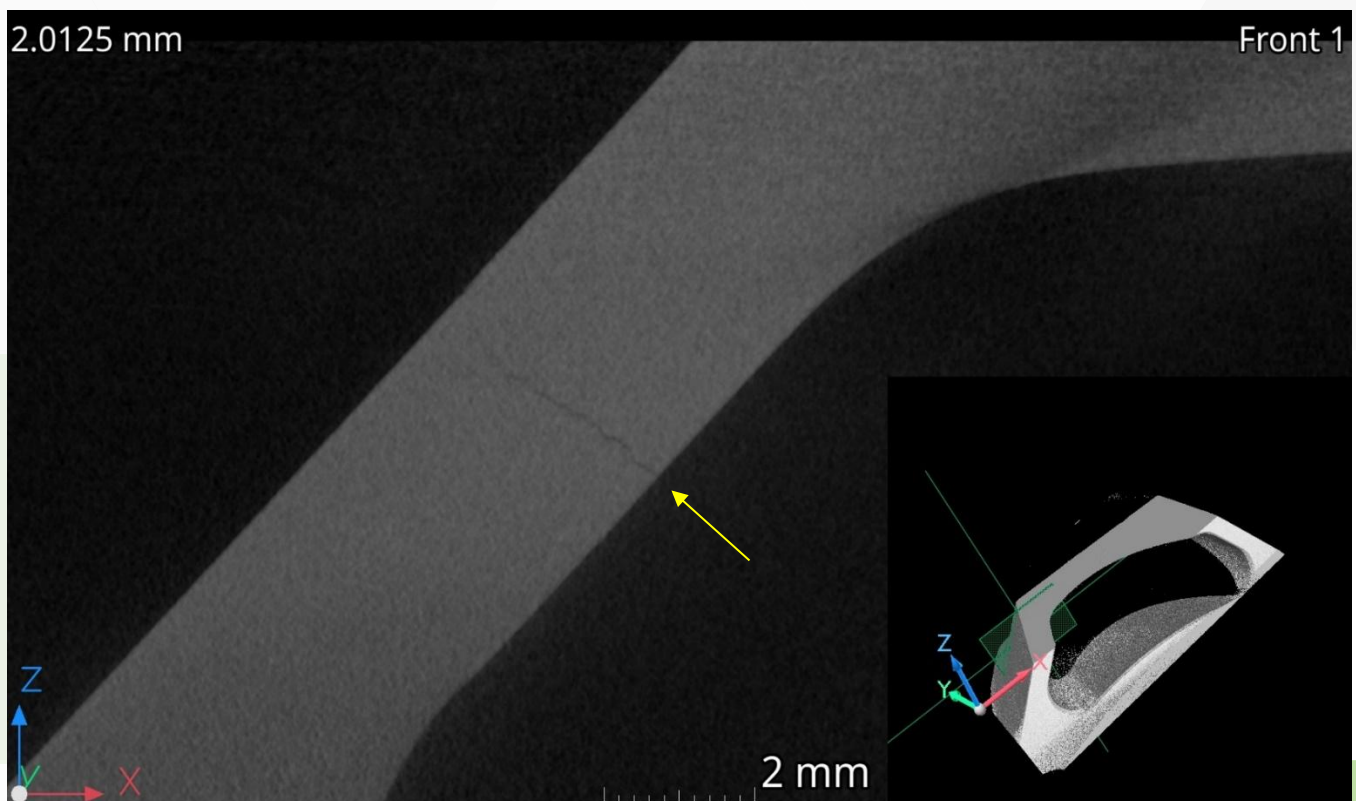


Figure 6: Tomographic cross-section of a fatigue crack in the gearbox housing.

DIGITALIZATION OF INTERNAL BONE STRUCTURE

How a bone resists mechanical loads does not depend solely on the amount of bone tissue. An important role is also played by the arrangement of trabecular bone, which continuously adapts to loading and changes depending on human age, the specific location within the bone, and the direction of the applied forces. Capturing these precise differences and helping determine how they translate into the mechanical properties of the bone was the goal of our work. As part of the research, we scanned 5 human shinbones (tibiae) from individuals of various ages (20-67 years) using micro-CT. The region of interest was restricted to the area near the knee joint, which allowed us to achieve sufficient resolution to capture the actual geometry of the fine trabecular network. From each measurement, regions of interest were subsequently selected at various locations within the bone along the primary loading directions (see Figure 7).

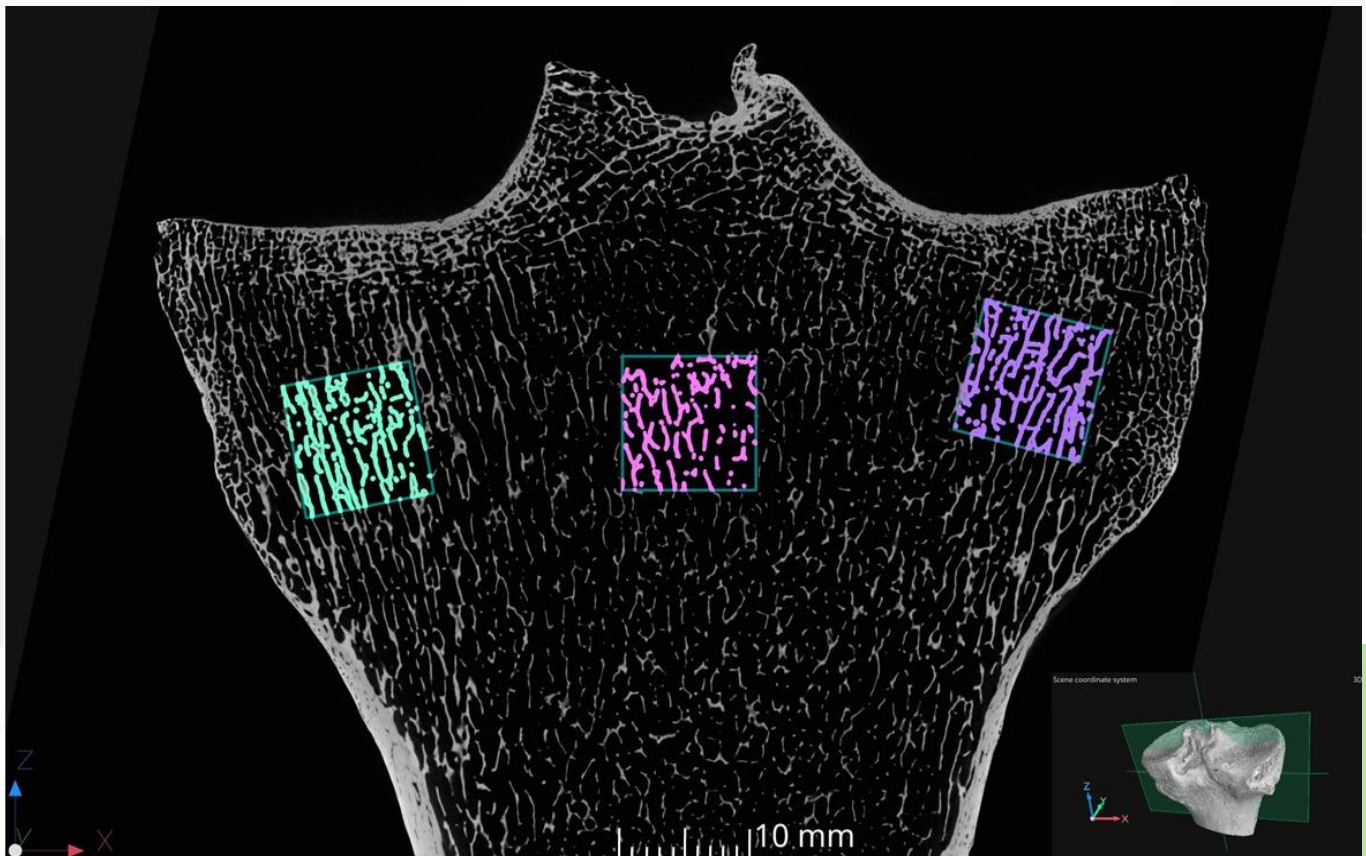


Figure 7: Location of regions of interest in the bone in the direction of principal loads.

3D models in STL format were subsequently created from the selected regions to serve as input geometry for numerical simulations. The goal is to identify how mechanical properties depend on the direction and location of loading, the orientation of the trabecular structure, and human age. This makes it possible, for instance, to compare whether the bone structure is stiffer precisely in the directions of loading to which it is most frequently subjected throughout life, and how significantly this dependency varies among individual samples.

Combining micro-CT with numerical simulations thus enables a better understanding of the relationship between its structure and mechanical function. The results can not only refine current knowledge of how bone transfers loads, but also map changes in mechanical behavior as a function of human age.

CEITEC STRENGTHENS COOPERATION WITH RIGAKU DURING A WORKING MISSION TO JAPAN

During their business trip to Japan, Prof. Jozef Kaiser and Assoc. Prof. Tomáš Zikmund visited Rigaku Corporation in Tokyo, one of the world's leading manufacturers of analytical and X-ray technologies. In Tokyo, they met with company representatives Mr. Omote and Mr. Takeda. The meeting confirmed the importance of long-term cooperation and opened avenues for further professional exchange.



Figure 8: From left: Y. Takeda, J. Kaiser, and K. Omote.

WHERE TO GO FOR SCIENCE AND TECHNOLOGY? WE'LL MEET AT THE INTERNATIONAL ENGINEERING FAIR

Autumn in Brno will once again belong to science, technology, and innovation. CT Lab will be presented at the International Engineering Fair. Come and see what happens behind the doors of top-tier laboratories and how research helps shape the technologies of the future.

- **October 6-9, 2026 - International Engineering Fair (MSV)** - Visit us at booth 025 + 027 in Hall A1.

Meet us at the region's most important industrial fair. We look forward to meeting you in Brno!

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