NON-DESTRUCTIVE ANALYSIS OF FUSION MATERIALS SAMPLES BY MICROTOMOGRAPHY, MICRO-TOMOGRAPHY DESIGN, FABRICATION AND TEST

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Introduction

X-ray microtomography is the only known tool that could meet the requirements of monitoring voids, micro-cracks and flaws in activated and completely assembled rigs, test modules and the Li-target back-wall.

The microtomographic systems have to fulfill rather difficult design constraints such as:

- high space resolution requirements;
- wide range of material densities and attenuation coefficients;
- capability to work out limited access angle problems.

A cone-beam X-ray microtomographic system has been constructed at the National Institute for Laser, Plasma and Radiation Physics (NILPRP), Bucharest-Magurele, Romania. Thus, we succeeded to deliver on the main goal of the current sub-task.

Experimental equipment

A general view of the microtomography system is presented in Figure 1.

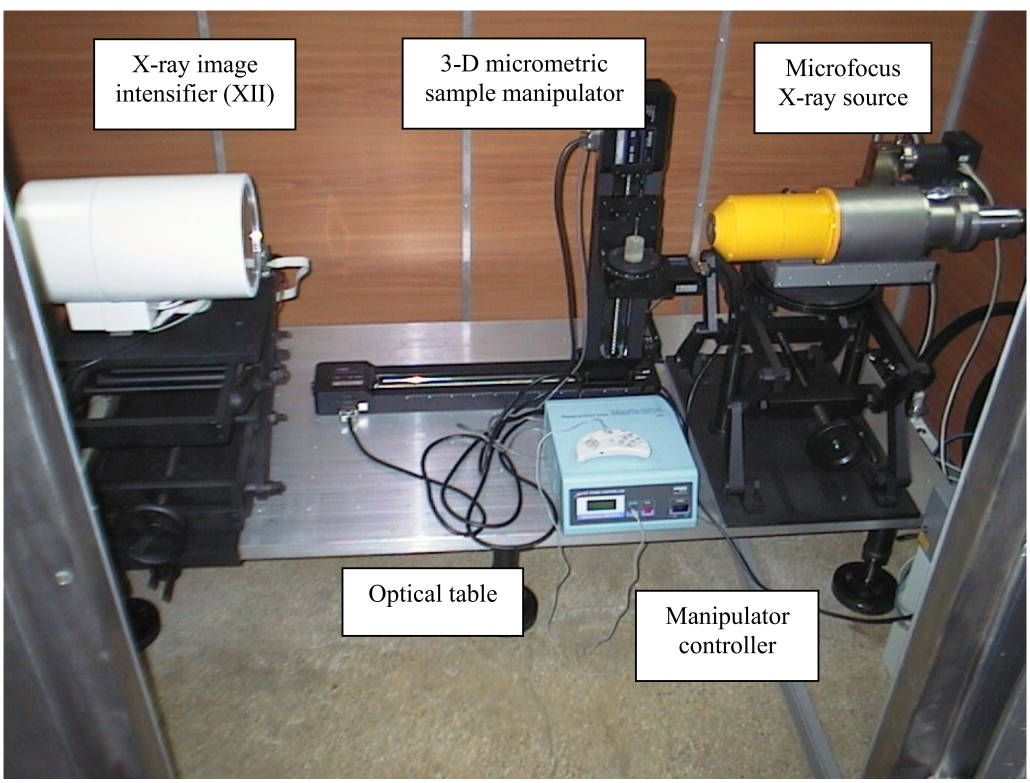

Figure 1. Fully 3-D cone-beam X-ray computer tomograph

The main components are: the open type microfocus X-ray source, the 2-D X-ray detection system and the micrometric sample manipulator. The X-ray source is mounted on a manually adjustable positioning support. The X-ray detection system is supported by a manually adjustable positioning device and eventually mounted on a micrometric translation axis and eventually supported. The whole tomographic system lies on an optical table which is placed inside a lead shielding cabinet. Two Dual CPU (2x2Ghz) networked workstations are used for the data acquisition and control and for the 3-D tomographic reconstructions and visualizations.

Table 1. MICROTOMOGRAPHIC SYSTEM: Overall Performances

	Items	Specifications
1	Microfocus X-ray source	Peak X-ray voltage(Vp): 160 kVp Max power: 20 W Feature recognition: 1 µm Min object-focus distance: 0.4 mm X-Ray cone: 170°
2	Detector elements	512x512 1024x1024 (maximum)
3	Micrometric manipulator X stage Z stage θ stage	 travel 500 mm, loading capacity 30 kg travel 300 mm, loading capacity 6 kg accuracy 0.03°, loading capacity 20 kg
3	Magnification Factor	<2000
4	Source-Detector Distance	1000 mm typical
5	Source-Object Distance[1)]	> 0.5 mm typical
6	Spatial Resolution[2)]	≅10µm
7	Density Resolution	> 0.5%
8	Digital Output[3)]	10 bits
9	Scanning Time[4)]	< 10min. (720 angle)
10	3D Reconstruction Time[5)]	< 2min. (256x256, 256lines) < 5min. (512x512, 256lines) < 20min. (1024x1024, 512 lines)
11	Effective Area of Detector	89681 mm^2 (169 mm diameter)
12	Probe Dimensions	Diameter <40 mm Height <500 mm
13	Projection Number	360 720
14	Scan Method	Cone beam CT (<512lines) Full scan (360deg.) Short Scan (180deg.+1/2 fan angle)
15	Output data format	Uncompressed 16 bits integer
16	Geometry Calibration Program	Center of Rotation *Vertical & Horizontal Alignment*

[1)] Minimum distance from X-ray focus to the object is 0.4 mm.

[2)] Mainly limited by stage control accuracy.

[3)] Digital output from frame grabber NI – PCI-1409.

[4)] Assuming 0.5sec./angle and stage motion.

[5)] Based on Dual CPU, 2GHz PC.

The selection of optimum tomographic configuration and components is based on test measurements of miniaturized sample mock-ups carried out on existent tomographs as well as on fully 3-D Monte Carlo simulations of X-ray radiation generation and transport. This configuration allows us to reduce the beam hardening artefacts and at same time to achieve very large magnification factors (up to 2000). The designed targets for space resolution, magnification and reduction of beam hardening are optimally satisfied by a combination of the image intensifier detection system and the open type 160 kVp X-ray source. These specifications are synthetically presented in Table 1.

Results and discussions

Currently, we are caring out the final phase of the system calibration and tuning. Micro-radiography images of a set of representative samples proved that the space resolution and the penetration power are sufficient for most of samples relevant for fusion material studies. As an example the radiography of a micro-switch is presented in Figure 2.

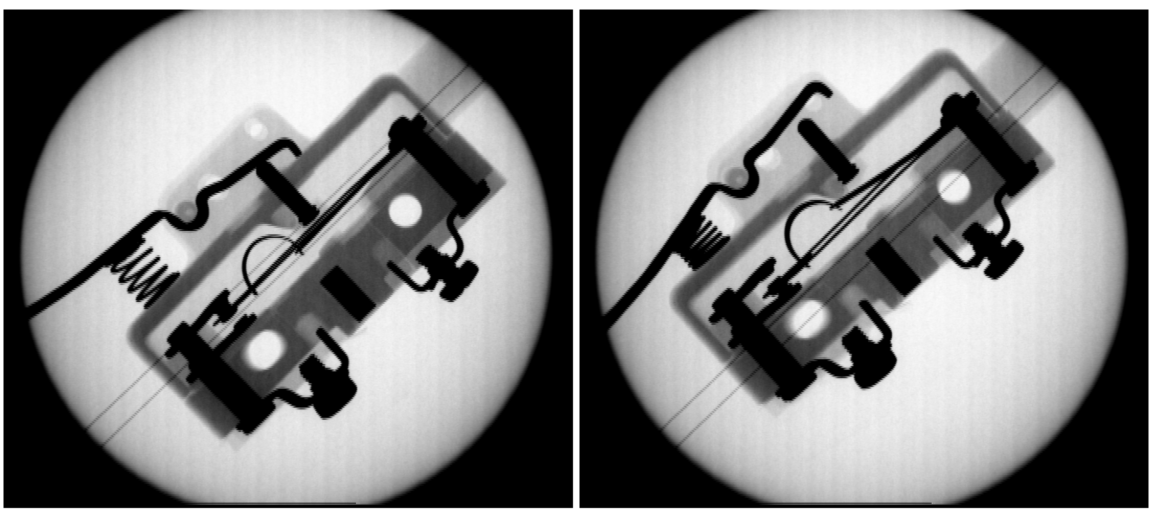

Figure 2: Micro-radiography images of a micro-switch in both states (opened and closed). Parameters of the radiography: U=50 kV, I=40 μA, 0.1 mm Cu filter

Finally, the new tomography system has been successfully verified by tomographic measurements. 3-D reconstructed images demonstrate that the specified parameters of the image quality have been achieved. As an example the tomographic reconstruction of a capacitor is presented in Figure 3.

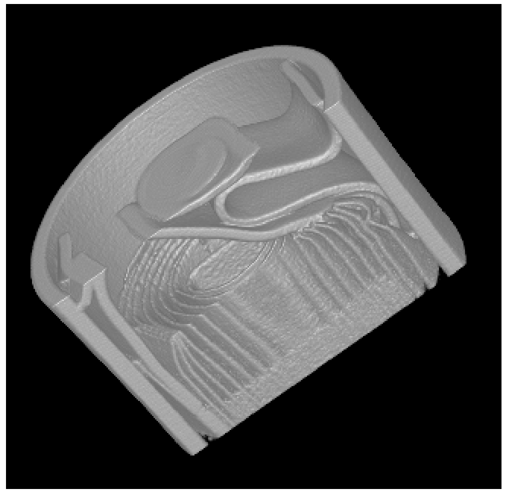

Figure 3.a: Tomographic 3-D reconstruction of a capacitor

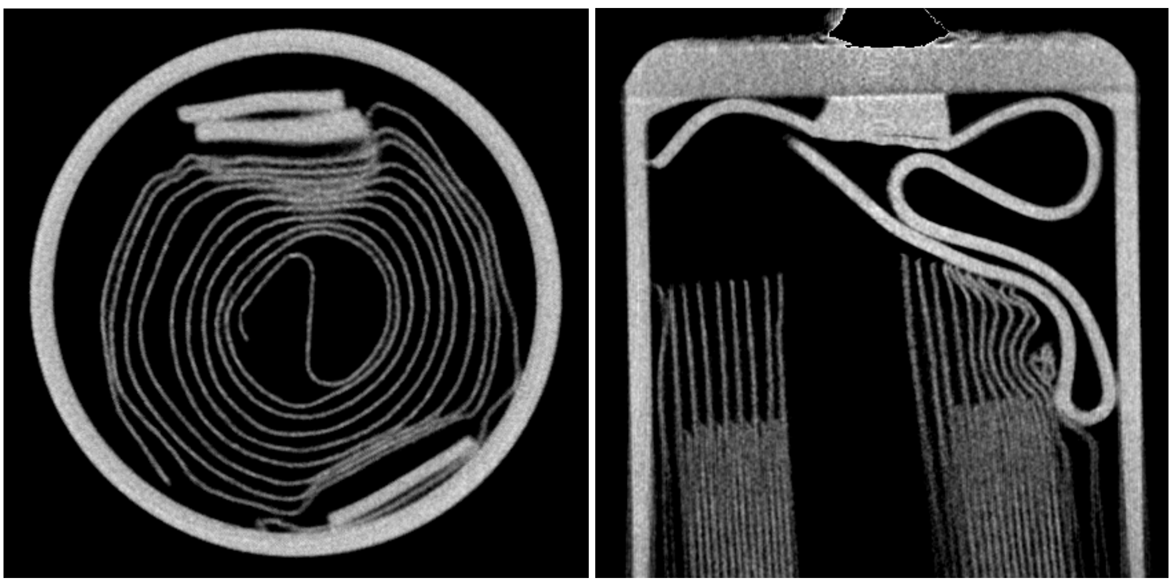

Figure 3.b: Axial section (left) and sagital section (right) through the reconstruction in Figure 3.a. One can notice the defect structure of the metallic coil.

The next activity is extensive NDT inspection of fusion materials miniaturized samples using the transmission micro-tomography system in order to establish a reference design for micro-tomography system for IFMIF environment conditions.

In addition to the fabrication of the microtomography system a consistent database for storing tomographic images of the miniaturized samples in different development and testing phases has also been designed and implemented. Taking into account the heterogeneity of the platforms used for data acquisition software (LabView) and for reconstruction software (mixing Fortran 90 and C++) we decided to use Microsoft Access for the database development. A VBA application was also developed in order to ensure user-friendly information retrieval of the parameters of the tomographic process: geometry and setup of the experiment, projections, reconstructed images, reconstruction parameters, storing type of information. The database is

implemented to
within the IFM

Conclusions

The newly de
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