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Optimization of Pre-Processing Parameters in the X-ray Microtomography (MicroCT) Image Reconstruction Process

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1. Introduction

The X-ray microtomography (MicroCT) is a non-invasive and non-destructive inspection technique of great importance in the industrial sector and widely used to study integrity and the structural dimensions of materials. An established and reliable technique has been improved for inspections of small structures and has the same principle as Computed Tomography, although some changes have been made in order to get higher resolutions [1].

Currently, tomography equipment with focus sizes ranging from 1 to 100 μm are developed. The tiny diameter of focus spot size is an important feature to be considered: the smaller it is, the better the resolution and detail of inspected structures [2].

The quality of the images obtained by Micro CT equipment depends on the nature of the X-rays, the type of detectors used, the parameters chosen for acquisition of the projections and, fundamentally, the parameters chosen in the image reconstruction process [3 and 4].

This work aims to optimize the parameters in the reconstruction process of microtomographic images and then evaluate the final quality of these reconstructed images. The parameters to be optimized are misalignment compensation, beam hardening, ring artifact reduction, smoothing and the histogram. The indicators of image quality evaluated are Contrast-Noise Ratio (CNR), Basic Spatial Resolution (SRb), Modulation Transfer Function (MTF).

For this, a phantom -- which is an object of known composition and geometry for the purpose of testing equipment -- of polymeric material was scanned. In the case of microCT, phantoms are also used to analyze and evaluate image quality parameters, and it is usually made of a material that simulates the characteristics of the objects under study.

2. Methodology

The microtomography used was a bench equipment manufactured by Bruker, model Skyscan 1273 (Fig. 1 a). The scanned Phantom is composed of a polymeric material, with 7 groups of 12 holes with diameters ranging from 0.1 mm to 1.6 mm (Fig. 1b).

The software used for the reconstruction of the microtomographic images was NRecon, version 1.7.1.0, based on the Feldkamp algorithm [5]. The reconstructed slices were saved as 8-bit files in *.BMP format.

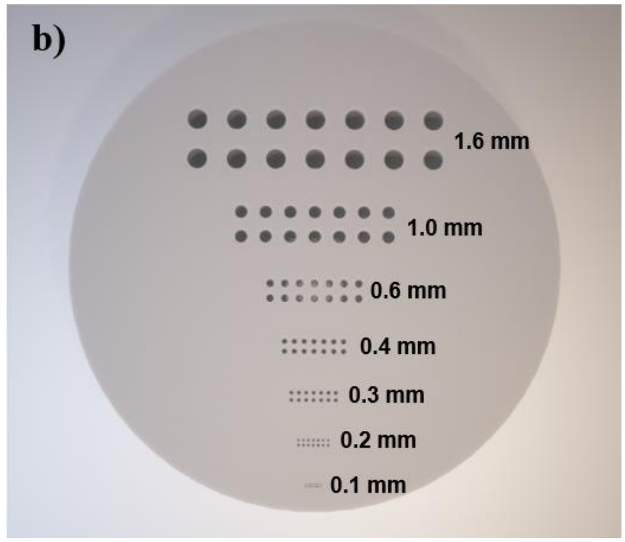

Figure 1: a) MicroCT equipment – Bruker model Skyscan1273; b) Phantom of polymeric material with holes ranging from 0.1 mm to 1.6 mm.

In order to determine the best value each parameter, they had to be adjusted manually in a try-and-error fashion using the preview function. The "fine-tuning" function was designed to make this adjustment somewhat easier by launching a series of previews. You may adjust one parameter at a time, while keeping all other parameters fixed. In this way, you may tune 4 parameters: post-alignment, beam-hardening correction, ring artifacts correction level and smoothing level. You choose the parameter to tune, and the parameter values are given such that they are centered on the current value (the valid range of the parameters are taken into account as well) with given step size. Then, the previews of the reconstruction were analyzed, and the one with highest quality was chosen as the ideal value for its respective parameter. Thus, the process was repeated for the other parameters. Posteriorly, choosing the dynamic range value of the image (histogram) was obtained from the previewing slice. Therefore, if the object is non-uniform, it is important to choose a slice, which goes through the dense parts of the object; otherwise higher values may be truncated in the final image.

The parameters optimized in the microCT reconstruction process are presented below:

Beam Hardening: effect that occurs because x-ray beams are poly-energetics. Thus, low energy photons cannot cross the Phantom, being absorbed by it. Due to such absorption, one can notice a blackening on the edges of the image, hindering its visualization. In the program, this parameter ranges from 0 to 100.

Misalignment Compensation: effect that can occur during the projections acquisition due to misalignments. If not corrected, the reconstruction can be blurry and present shadows that hinder the ideal view. In the program, this parameter has no variation range. You can choose any value.

Ring Artifact Reduction: effect that occurs when there are faults in elements of the x-ray detector, for example, presence of defective pixels (bad pixel). In the image, one can notice circular shapes along its radius, (hence the name “ring”). In the program, this parameter ranges between 0 and 20.

Smoothing: used to “smooth” the image, reducing its noise (represented by a grain). If used carelessly, it may blur the image. In the program, its range is from 0 to 10.

Histogram: This function determines the dynamic image range when converting from real numbers into integers determined by the output file format.

3. Results and Discussion

The first measure calculated was the CNR. First, it was determined which pair of holes would be used from the coronal view, and it was chosen as the smallest pair of holes that could be distinguished with the naked eye. Therefore, the pair of holes chosen was 0.2 mm in size, the intensity profile for the selected area was plotted and the value obtained was 4.93.

In order to calculate the basic spatial resolution (SRb), it was necessary to obtain the modulation transfer function (MTF), considering 20% of the beam intensity profile and taking measurements from the edge of the Phantom image. The calculated value for MTF was 7.0 pl/mm (line pairs per millimeter) and the SRb was 71.4 µm.

Figure 2 shows a 3D model of the reconstructed phantom in which it is possible to fully identify the 7 groups of holes.

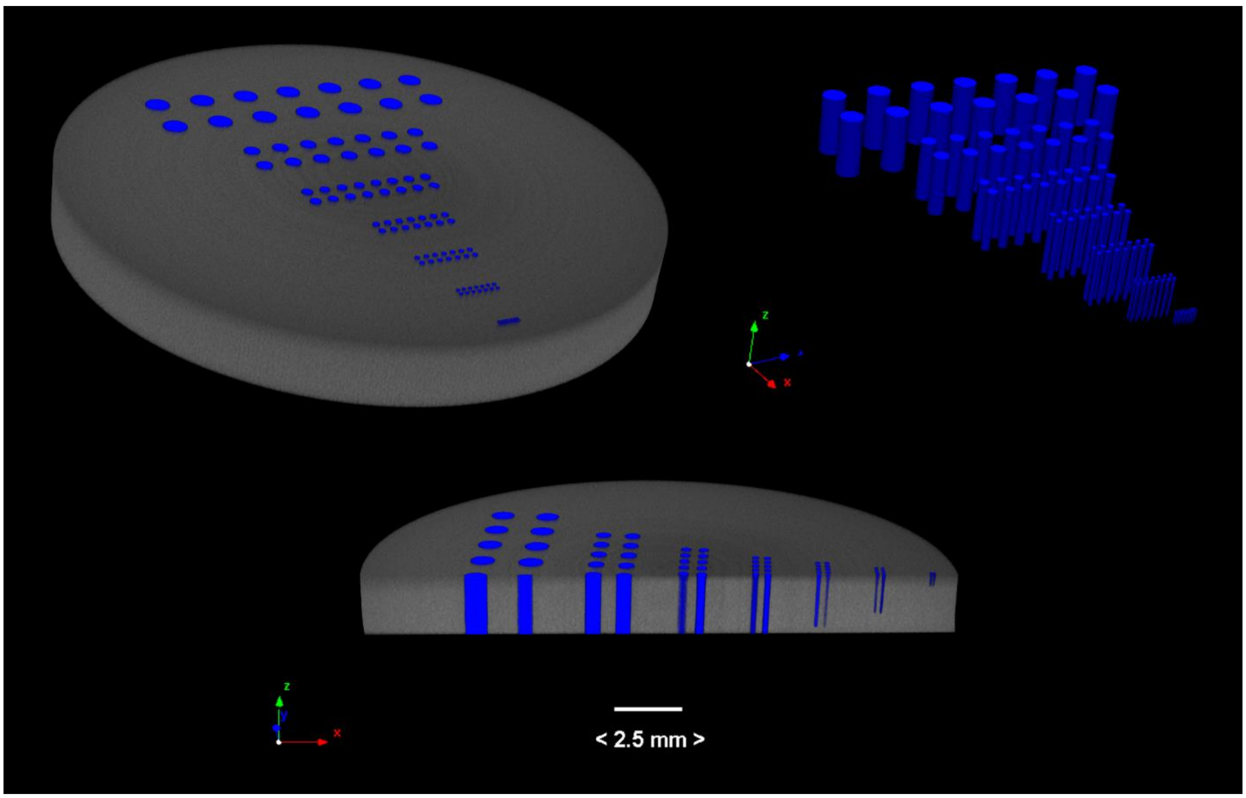

Figure 2: 3D model showing that it was possible to identify the 7 groups of 12 holes with diameters ranging from 0.1 mm to 1.6 mm.

4. Conclusions

The choices made during the reconstruction process proved to be assertive. Thus, it was possible to identify in the phantom the set of holes with the smallest diameter (0.1 mm or 100 µm).

The MTF shows the real resolution of the system, that is, the limit of the ability to differentiate very close structures. In this study, the value obtained was 7.0 pl/mm, indicating a spatial resolution of 71.4 µm, which justifies the visualization of smaller diameter holes.

Noise did not greatly affect the contrast of the images, considering that a value of 4.93 was obtained for CNR, and the minimum value required by the ASTM E 2698 standard is 2.50.

Optimizing the parameters at each stage of a microCT scan (data acquisition and reconstruction) ensures better quality in the final images. With this, the need for image post-processing is reduced, which would demand for less time and computational power.

Acknowledgements

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