Evaluation of the influence of acquisition parameters of microtomography in image quality applied by carbonate rocks

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Abstract. X-ray computed microtomography is a powerful nondestructive technique for 2D and 3D structure analysis. However, parameters used in acquisition promote directs influence in qualitative and quantitative results in characterization of samples, due image resolution. The aim of this study is value the influence of theses parameters in results through of tests changing these parameters in different situations and system characterization. Results demonstrate those pixel size and detector matrixes are the main parameters that influence in resolution and image quality. Microtomography was considered an excellent technique for characterization using the best image resolution possible.

1. Introduction
Carbonate rocks are sedimentary rocks widely studied due the importance in petroleum extraction after pre-salt discovery. This type of rock represents half of the petroleum extraction in Brazil [1, 2].

X-ray Computed microtomography (MicroCT) is an important non-destructive technique for analysis of inner structures with high resolution in the order of micrometer. Its physical principle are based on attenuation of X ray by matter that result a gray scale image proportional to the material density [3].

This technique has been used to characterize carbonate rocks in relation to porosity and pore's size distribution in this work [4, 5]. However, the choice of acquisition parameters is essential to obtain the best resolution and image quality, ensuring the most accurate results [6, 7, 8].

The aim of this study is evaluate the influence of these acquisition parameters in image quality and through of obtained results optimize these parameters to obtain the better image quality for this application.

2. Materials and Methods
The system used was SKYSCAN/BRUKER High Energy model 1173, installed in nuclear instrumentation laboratory (UFRJ). The specimen was an Indiana Limestone and was acquired changing the acquisition parameters like pixel size, detector matrix, and frames number (case 01 – case 04). These cases can be visualized in table 1.
The reference case was using detector matrix 2240 x 2240 pixels, pixel size of 18.16 µm, 130 kV and 61 µA of voltage and current, additional filter of Copper of 0.5 mm, 5 frames and rotation of 360°, represented in table 1 like case 01. These parameters were chosen according many references of works in this area [6].

After the acquisition, the projections were reconstructed in the software NRecon with the best corrections parameters. The next step was segmentation that was realized in Avizo Fire 9.01 with the watershed’s method [9].

The watershed’s method is based in one or more choices of threshold by operator and the software does the segmentation through of the gradient image and provide the binary image. Also on Avizo Fire, it was obtained the porosity and the porous’ size distribution for each cases, where the porosity can be calculate through of the equation 1.

\[
\text{Porosity} = \frac{\text{Pore's Volume}}{\text{Total Volume}}
\]  

(1)

To analyze the results, it was done a characterization of the system to obtain information about the spatial resolution. In order to characterize the system in relation the influence of detector matrix, pixel size and spatial resolution, it was realized a test of modular transfer function (MTF), where is possible calculate the resolution.

This test was realized using the inclined plate method through of a radiography of a Tungsten (W) plate inclined 5° with the system calibrated to work with voltage of 130kV and current of 61µA, and a additional Copper filter of 0.5mm [10]. The radiography was analyzed on software Isee, as figure 1, and spatial resolution was calculated by the equation 2.

Figure 1 - Analyze of Tungsten plate radiography on software Isee.

The test was realized with two different detector’s matrix, 1120x1120 pixels and 2240x2240 pixels, and different magnification and pixel size.
To obtain the signal-noise relation (SNR), it was obtained an empty projection, a projection without sample, using different detector’s matrix and frames numbers. The projections were analyzed on software Isee in 25 different rectangle regions of interest of 20x55 pixels, as in figure 2.

\[ \text{Resolution} = \frac{1}{2x(MTF_{20\%})} \]  

3. Results and Discussion
With the results, it was possible generate a graphic of spatial resolution vs pixel size in two detector matrix and a graphic of spatial resolution vs magnification also in two detector matrix, figure 3. Observe that for different detector matrix the same magnification is obtained with different pixel size, for instance, when you use detector matrix of 2240 x 2240 pixels you use a pixel size two times less than when you use detector matrix of 1120 x 1120 pixels.

Figure 2 - This picture illustrate the localization of ROIs on empty projection

Figure 3 - Graphic of the relation between Spatial Resolution and Magnification, on left, and between Spatial Resolution and Pixel Size
It was possible also generate a graphic of SNR vs frames number, figure 4, through of the test previous cited and evaluate the best or approximated frames number ideal for the best image quality.

![Graphic of SNR vs Frames Number](image)

**Figure 4 - Graphic of the relation between signal noise relation and frames number.**

It is possible to observe in graphic on figure 4 that the curve begin to have a constant behavior from 15 frames. However, comparing the acquisition time of the case 1 and 4, when the frames number is 15, it is observed that the acquisition time in case 4 is three times great than case 1. It is necessary to balance the gain and the time acquisition to choice this parameter.

The porosity results obtained in each case can be visualized on table 1. It is possible to observe through of the results a strong influence of pixel size (case 3) and detector matrix (case 2) in resolution compared to reference case (case 1).

**Table 1 - Table of the acquisition parameters and the porosity found in each case**

| Case | Detector matrix | Voltage and current | Pixel size | Frames | Add Filter | Rotation | Acquisition duration | Porosity (%) |
|------|-----------------|---------------------|------------|--------|------------|----------|----------------------|--------------|
| 1    | 2240 x2240      | 130kV e 61µA        | 18.16 µm   | 5      | Cu 0.5 mm  | 360°     | 1:38:26              | 6.99         |
| 2    | 1120 x 1120     | 130kV e 61µA        | 36.32 µm   | 5      | Cu 0.5 mm  | 360°     | 0:31:59              | 2.97         |
| 3    | 2240 x 2240     | 130kV e 61µA        | 29.91 µm   | 5      | Cu 0.5 mm  | 360°     | 1:38:28              | 2.20         |
| 4    | 2240 x 2240     | 130kV e 61µA        | 18.16 µm   | 15     | Cu 0.5 mm  | 360°     | 4:18:07              | 5.83         |

It was generate a graphic with results of case 02, figure 5 and it is observed that the spatial resolution for the second case, where the pixel size is 36.32µm and detector matrix of 1120x1120 pixels, is approximated 60µm. Then, pores less than this value will not be counted. It justified why don’t have counting on the first interval of pore’s size.
On case 03, 29.91 µm of pixel size and detector matrix of 2240x2240 pixels, the spatial resolution is little more than 70 µm. This way, pores on the first interval of pore size and majority of second interval are no counting resulting in a low porosity, as on figure 6.

It is believed that a bigger SNR result in a better image quality and the frames number can be associated with these improvements. In this case the pore’s boundary is more defined than in the case 01, where the frames number is 5, and it is related with the sharpness.

With this improvement on the sharpness little pores were counting and the boundary was not super estimated on segmentation. Other point is the acquisition time, that in case 04 is three times greater than in case 01.

Besides that, on figure 7, was possible to observe the difference between each case in relation spatial resolution and sharpness. For this application, to characterize carbonate rocks, the technique provide porosity, pore's distribution, even as pore space and connected pores, like on figure 8.
4. Conclusion
It is possible to conclude that all parameters influence in image quality with different intensity and it is necessary to optimize these parameters correctly to obtain the best image quality on the best acquisition time.

Detector matrix and pixel size were the main influencing parameters in relation to spatial resolution, and for this system and this type of sample the best detector matrix is 2240x2210 pixels and the best pixel size is the smallest provided for the system. However, it is also necessary to balance the pixel size and frames number with the time and the gain obtained with this improvement.

Microtomography is an excellent technique for image analyzes and with the best acquisition parameters is possible to obtain accurate results without damaging the samples.

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