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An investigation of radiation instability on reconstruction quality in tomography

V B Bessonov, V V Klonov, I A Larionov and A V Obodovskiy
Saint Petersburg Electrotechnical University "LETI", 197022, Saint-Petersburg, Russia
E-mail: vbbessonov@yandex.ru

Abstract. The paper describes the experience of detecting defects in layered structures using microfocus tomography. The basic features of the equipment for microfocus tomography are given. The sizes of defects (pores and inclusions) and their location in the object are analyzed.

Modern tomograph is a software and hardware complex in which the obtaining of necessary information for the reconstruction of the object’s section is associated with its consistent radioscopy from a large number of angles [1].

Obtaining projections is associated with such parasitic phenomena as digital noise and scatter in the intensity of exposure of the X-ray receiver in a series of tomographic projections. In this connection, it seems expedient to investigate the effect of these phenomena on the quality of the rebuilt section [2].

To solve this problem, a specialized computer program was developed in the Qt Creator environment. The program allows to recreate the digital noise effect of an ideal tomographic projection for further investigation of the influence of this parameter’s value on the reconstructed tomographic section quality.

The addition of digital noise (figure 1) was carried out using the following relationship:

\[ \Delta = (\text{RND} \cdot k) - k/2, \]

where \( \Delta \) – brightness added to the original pixel of the image; \( \text{RND} \) – random variable in a given range; \( k \) – coefficient that allows to vary the overall level of digital noise in the image.

![Figure 1](image-url)

Figure 1. Adding to the original image of digital noise: (a) – initial projection; (b) – projection with artificially added noise.
The program also implements the possibility of creating a set of tomographic projections with a spread in the intensity of exposure of the X-ray receiver with a given value of the instability of the X-ray source. The variation of the spread (figure 2) was carried out according to the following relationship:

\[ \Delta RND_k = (RND - 0.5) \cdot k + 1. \]

**Figure 2.** A projection series with an imitation of the scatter of radiation intensity.

With the help of the written program, a set of tomographic projections with different levels of digital noise was created. Superposition of noise was carried out using relationship represented above, wherein the noise level is determined by the coefficient \( k \). Projections with different values of \( k \) are shown in further sections. Also under each section there is an example of the projection of the corresponding level of noise pollution (figure 3).

**Figure 3.** Evaluation the influence of digital noise on the quality of reconstruction: (a) \(- k = 30 \); (b) \(- k = 50 \); (c) \(- k = 100 \).
From the images shown above, it can be seen that even a small amount of digital noise in the image influences on the quality of the reconstruction, so it is worthwhile to pay the greatest attention to its filtering in the set of projection data.

When evaluating the obtained data, it is worthwhile to note that the noise component appearing during the reconstruction takes different values for the slices reconstructed from the same number of projections and increases with the increase in the noise component due to the imperfection of the X-ray receivers. Hence, we can conclude that the noise of the reconstruction depends on the noise of the projections, which in turn indicates that the effect of projective noise on the quality of the reduced cut increases nonlinearly as its magnitude increases. The graph in figure 4 most clearly reflects this relationship.

![Figure 4. Dependence of the projection noise on the noise of the shear recovery.](image_url)

The results of a simulation describing the non-uniformity of radiation during a set of projection data are presented in the figure 5.

![Figure 5. Evaluation of the radiation effect unevenness on reconstruction.](image_url)
The data presented in figure 5 clearly illustrate that the non-uniformity of radiation does not have a significant effect on the reconstruction quality. However, in this case it should be noted that imitation of non-uniformity was made within the linear area of the dynamic range curve of the radiation receiver.

Speaking about microtomography like a method of research (usually, inanimate objects), that makes it possible to obtain tomograms with a resolution at the level of one micrometer, due to the peculiarities of the used physical and technical conditions of shooting (small anode currents of the X-ray tube and, consequently, large exposition time, which is necessary for obtaining one projection), it is advisable to analyze, how much projection data or how small the angle of rotation of an object is required to achieve the required quality of reconstruction. The tomographic section was reconstructed using 200, 800 and 1600 projections. The restored tomographic sections are presented in figure 6.

![Figure 6](image)

Figure 6. To explain the effect of the number of projections on the quality of reconstructions in tomographic images: (a) – section reconstructed from 200 projections; (b) – section reconstructed from 800 projections; (c) – section reconstructed from 1600 projections.

As can be seen in figure 6(a), on a section reconstructed from 200 projections, the artifacts from the boundaries of the object have a significant effect on the quality of the reconstruction. With 800 projections, artifacts are almost eliminated. On a cut all details of the investigated object are visible, and there are no defects. The use of 1600 projections does not introduce any noticeable changes, which indicates the inexpediency of further increases in the number of projections in this study. Thus, it can be concluded that for this simulated test object, using the condition of “necessity and sufficiency” of information for diagnosis, it is possible to significantly reduce the study time from 2 to 8 times.

Based on the results of the conducted research, it seems expedient to develop a specialized mathematical model that includes small-sized and low-contrast details, allowing to estimate the number of projections necessary to achieve the required quality of reconstruction.

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