1.9.1. ITERATIVE INDUSTRIAL TOMOGRAPHY INTENSIFIED BY SUPERCOMPUTERS

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The report considers the basic principles of industrial computer tomography in very prevailing case when the input acquisition X-ray data are acquired with the lack of observation angles, number of projections or X-ray source energy respectively. The common way to fill up the absent or fuzzy data is to use the iterative methods for inverse problem solution using any kind of a priory knowledge available. In this case the final image is achieved by a successive approximation approach. In our monography ("Iterative methods of tomography", Minsk, Nauka I Technika, 2009) we synthesized the fundamentals of the method. However, in practice the iterative procedure is characterized:

1) by very low rate of convergence (and therefore their performance on conventional computers requires a significant time to achieve good results;

2) requires much memory space to store every iteration step an image vector, projection data and the necessary matrix of coefficients. A natural way to overcome these shortcomings and improve the image quality is to provide high-speed multiprocessor computational systems, as well as the development of new parallel algorithms for 3D tomographic reconstruction. We describe here the application to the reconstruction problem the parallel computing supercomputer family "SKIF" with a broad spectrum of performance (up to billions operations per second), set up jointly by teams from Russia and Belarus.

In the laboratory of computer diagnostics we developed the effective synchronous parallel computing algorithms and software codes for the programming language C ++ and MPI for a three-dimensional tomographic reconstruction within cone-beam circular acquisition geometry. Debugging the code and numerical calculations were carried out on K-1000 supercomputer family "SKIF". The number of the "SKIF" processor cluster nodes which carried out numerical calculations was usually in the range of 30 to 90. To implement the parallel three-dimensional tomographic reconstruction the voxel form of parallelism was used. The experimental data to validate the technique were acquired with the help of X-ray scanning machine Securescan and Pulmoskan – 760U developed by the Minsk company "Adani". The scanners are supplied with Γ-shaped linear detectors with a 3136 recording elements size of 0.8 mm, X-ray tube and linear scanning system (along the line perpendicular to the line of detectors). The three-dimensional tomograms size was $580 \times 280 \times 580$ volumetric elements with a resolution of $0.16 \times 0.16 \times 0.16$ mm.

Figure 1 shows three different reconstructed spatial image positions of one of the separators. Figure 2 shows one of the cross sections of the separator with detected small (about 1.5 mm diameter) casting pore.

The number of acquired projections was 60 (instead of 500 usually used) within 180°. The technique allows 50 – 100 times to reduce the time of the tomographic reconstruction and provides an opportunity to restore objects with dimensions 512×1024 voxels with simultaneous storage all the necessary data in the memory unit of 4 Gb.

The other application area for the iterative tomography is the minimization of X-ray source energy being preferable due to many reasons. The situation appears in case of tomographic imaging of articles with large difference in "X-ray length" in different directions. Then, if the X-ray source energy is adjusted for minimum length, a strong beam hardening effect in longer directions will corrupt respective projected images thus

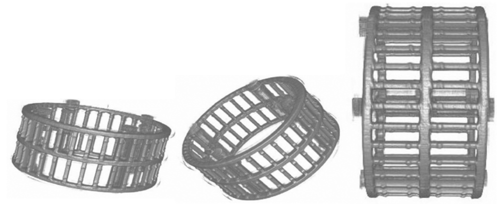

Fig. 1. Reconstructed images of the separator

Fig. 2. Separator cross section with the pore

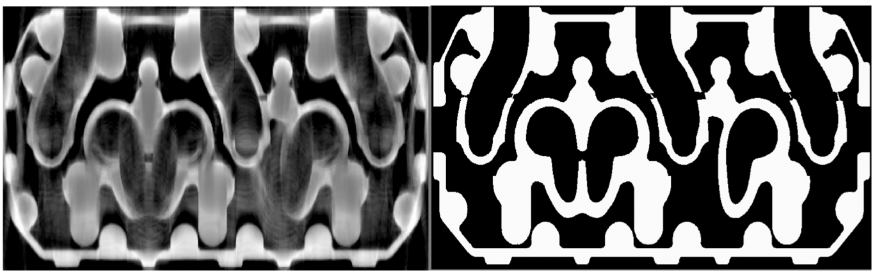

Fig. 3. Cylinder block head images acquired

worsening the reconstruction result. The iteration shell reconstruction using a priory information on the binary structure and beam hardening effect compensation improves the result cardinally. Figure 3 shows the result of the 3d reconstruction of the cylinder block head with minimum / maximum X-ray length ratio is close to 10. The usage of the regular Feldkamp algorithm and X-ray projections acquired with the X-ray tube adjusted to the minimum length will result in complete 3D image degrading, thus not shown. The application of the simple iterative algorithm using voxel-type representation of the object is shown in the fig. 3, left which is one of the cross sections of the reconstructed image. The quality of the image became much better but the blurring effect is still considerable.

Figure 3, right is the result of iteration reconstruction applying shell approach. This is the kind of the prior information about the binary structure of the object. It is approved that all details of the object are restored with the resolution above 0.5 mm despite of significant deterioration of initial projected data.