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Improvement of Ultrasonic CT images for wood by consideration of the anisotropic acoustic property and interpolation based on ML-EM

ML-EM 法による音速異方性と補間を考慮した木材の超音波 CT イメージの改良

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1. Introduction

In ultrasonic TOF computed tomography, Maximum Likelihood -Expectation Maximization is one of a method of image reconstruction. There are some reports [1-4] on the nondestructive inspection of wooden pillars by using ultrasound. The filtered back-projection (FBP) method, well-known existing algorithm was modified to reconstruct CT images from incomplete TOF profiles. However, the reconstructed image of FBP has a problem. The FBP gives negative value for the pixels. ML-EM algorithm has been applied in medical. It gives positive value for the pixels in calculation process, and absorption, scattering, resolution can be corrected in ML-EM process [5-6]. In this paper, we proposed an approach for wooden inspection by using ultrasonic CT based on ML-EM method.

In our study, in order to decrease artifacts in reconstructed images, anisotropic acoustic property was considered in the ML-EM method. And to increase the image quality, the interpolation of TOF data was applied in the ML-EM imaging process. The effect of image quality level and TOF data number of interpolation was examined in detail by using the wooden phantom.

2. Experiment

2-1 Measurement of TOF data

In our system, the method of measurement of TOF data was same as the method that was explained in the report of Yanagida et.al [7].

2-2 Anisotropic acoustic property

The sound velocity in wood changes with the direction of the ultrasound propagation path. The sound velocities are different between the transmission path near the center and near the edge of wood pillar[8] (Fig.1). Since ultrasonic CT image was reconstructed based on spatial distribution of sound velocity, some ring artifacts appeared in reconstructed image with wood anisotropic acoustic property.

To resolve this problem, "average sound velocity of gap " method was performed in our system. The i-th TOF data τ_i is corrected to $\hat{\tau}_i$ as following equation,

$$\hat{\tau}_i = \frac{l\tau_i}{c_0\bar{\tau}},$$

$\bar{\tau}$ was the average TOF of every gap. When $\hat{\tau}_i$ was compared with the average value, $\hat{\tau}_i$ was only related to the sound velocity TOF in the same gap, other sound velocity TOF wound be irrelevant. Ultrasonic CT image was reconstructed by using $\hat{\tau}_i$. Since the influence of the anisotropic acoustic property was reduced, the artifact level of reconstructed image decreased.

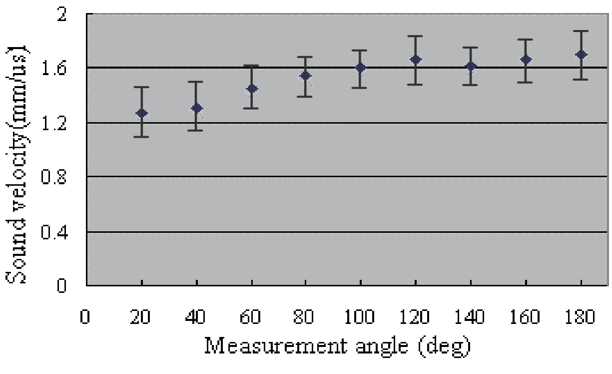

Fig.1. The dependence of sound velocity for the center angle.

2-3 Angle interpolation

The circumference of the wood specimen was 630mm and the wavelength of ultrasound of 68kHz was about 20mm. 36 measurement points were placed on the circumference. The distance of interval was about 17mm. All measurement paths were 306. It takes about two hours to obtain 306 TOF for one CT image. So, the number of data that can be measured is thought that 306 were near the upper bound timely and spatially. However, the 306

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data was not enough to obtain clear CT image. To raise the pixel level, angle interpolation was used in imaging process. The TOF data was obtained measured with fan-beam geometry of non-equal and coarse intervals. The obtained TOF profiles are converted into the small and regularly-interval data by the spline interpolation. After the interpolation, the number of the data becomes 630 and 2556 for 10° and 5° interval, respectively.

3. Results and discussion

Four piece of hardwood were prepared as test specimen. The artificial defects that were set on the same place in the test sample, the centers of defects from centers of the wooden pillars is 50mm. Diameters of artificial defect were 18mm, 22mm, 33mm and 40mm. The diameter of the inspection object was 220mm(Fig.2).

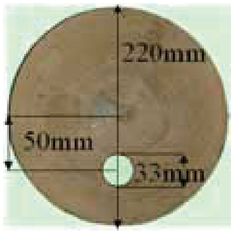

Fig.2. The inspection object

The reconstructed images based on ML-EM method are shown in Fig.3.

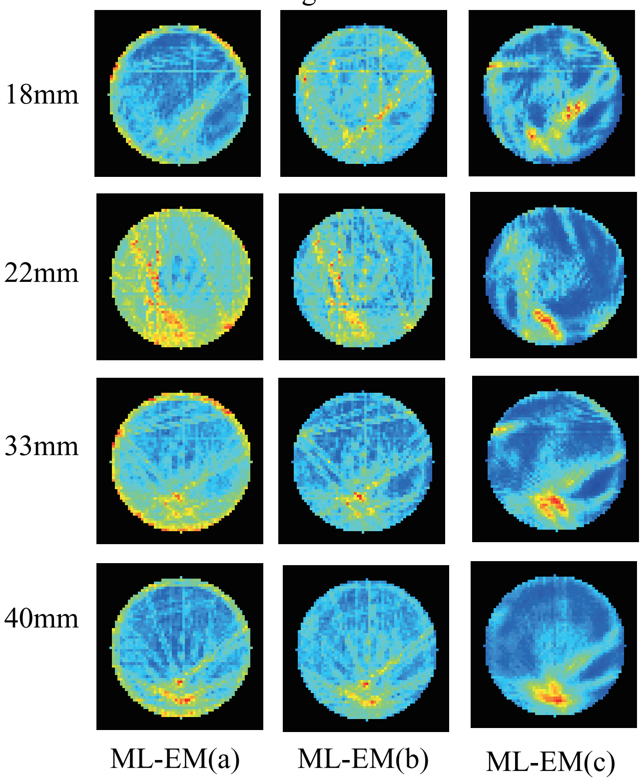

Fig.3. The reconstructed images by experimental data for various defect sizes and reconstruction methods

The images reconstructed by ML-EM(a) method was used only 306 measured TOF data. Some artifacts were recognized in the images, and the defects were not clearly observed by only 306 measured TOF data. In ML-EM(b) method, acoustical anisotropy is considered. The line artifacts were reduced considerably, and the artifact on the edge of reconstructed images was disappeared almost. ML-EM(c) method adopted interpolated TOF data and “average sound velocity of gap” method at the same time. By the reconstructed method of ML-EM(c), defect was clearly reconstructed by 5° interpolation, and artifacts were disappeared almost, the image quality was improved.

For the CT images of Fig.3, artificial defects over 22mm diameter were detected very accurately. While the artificial defect of 18mm diameter was detected on the CT images, it cannot be clearly observed. The reason was thought to be because the diameter of the artificial defect was smaller than the wavelength of the ultrasonic wave (about 20 mm).

When the ML-EM method was used for the ultrasonic CT of wood, the 306 TOF data was not enough to obtain clear images. To apply ML-EM method for ultrasonic CT, we should obtain more TOF data or use an interpolation in imaging process. Because of anisotropic acoustic property of wood, the artifacts appeared in reconstructed images, artifacts disappeared almost by using “average sound velocity of gap method” and the high quality images were obtained.

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