Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 7-8, 2015

Comparison of step-and-shoot and continuous scanning methods in cone-beam computed micro-tomography for NDT

Jun Beom Park[a], Hanbean Youn[a], Seung Ho Kim[a], Junwoo Kim[a], Soohwa Kam[a], Eunpyeong Park[a], and Ho Kyung Kim[a,b*]
[a]*School of Mechanical Engineering, Pusan National University, Busan, South Korea*
[b]*Center for Advanced Medical Engineering Research, Pusan National University, Busan, South Korea*
[*]*Corresponding author: hokyung@pusan.ac.kr*

1. Introduction

Computed tomography (CT) is an emerging technology for the non-destructive testing (NDT) of high precision manufacturing to enhance the production reliability. In order to use the CT for the NDT, high-speed inspection is essential for a higher production yield. However, conventional high resolution CT systems usually require terms of minutes to take exam because they employ the step-and-shoot protocol to avoid motion blur during the image acquisition. Unlike the step-and-shoot protocol, continuous scan protocol, which simultaneously acquires projection images during the rotation, can only require terms of seconds because it can ignore the time delay between “stop and go” steps of rotation [1]. Continuous scan is used for medical CT systems. However, the loss of system resolution originated from the motion blur cannot be avoidable.

The purpose of this study is to compare the quality of images obtained from the step-and-shoot and continuous scanning methods in terms of system resolution. In addition, this study aims to determine the fastest continuous scanning speed with image quality enough for the defect inspection.

2. Material and Methods

2.1 Experimental setup

Figure 1(a) shows the experimental set up used in this study. We used tungsten target X-ray source having maximum current and voltage as 1 mA and 50 kVp, respectively. The focal spot size of X-ray source was 35 μm. We applied 40 kVp tungsten spectrum with additional 3-mm-thick aluminum filtration for the experiment. The complementary metal-oxide semiconductor (CMOS) detector with 0.099 mm pixels arranged in a 1032 × 1548 format was used for the flat-panel imager. We placed the thin wire phantom, as shown in fig. 1(b), between the X-ray source and detector. The distances from the source to detector and object were determined to be 656.3 mm and 437.5 mm, respectively, therefore the magnification factor of the system was approximately 1.5. The detailed image acquisition parameters are summarized in table 1. We note that the total scan time of the step-and-shoot and continuous scans are 10 minutes and 72 sec (0.2 sec/times × 360 projections), respectively [2].

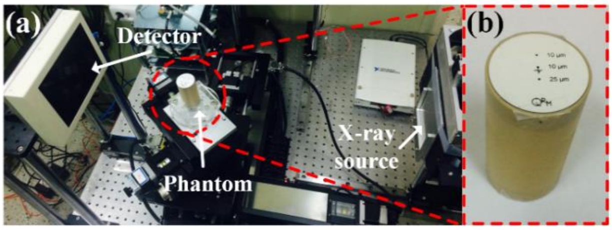

Fig. 1. The computed tomography system that was constituted for experiment (a), the thin wire phantom that was used in experiment (b).

2.2 Measurement of MTF

To evaluate the system resolution between the step-and-shoot and continuous scans, we measured modulation-transfer function (MTF) by using the wire phantom. To calculate MTF in CT, 3 degree-slanted wire was used for the application of the fine sampling method. Then, we applied the Hankel transform to the slice image which contained the point spread function (PSF) of the system. The Hankel transform of the PSF *f(r)*, is defined by

$$T(f) = 2\pi\int_0^\infty f(r)J_0(2\pi fr)rdr, \quad (1)$$

where J_0 is the zero-order Bessel function of the first kind [3].

2.3 Effective aperture

As a single descriptor for system resolution, we used the concept of effective aperture:

$$A_{eff} = [2\pi\int_{-\infty}^{\infty} T^2(f)fdf]^{-1}. \quad (2)$$

The qualitative meaning of the effective aperture is the resolution limit of system in spatial domain. We can expect that the size of effective aperture can be larger for higher rotation speed in continuous scan protocol. Therefore, we can characterize the effective aperture in terms of rotation speed and then, compared it with the typical size of defect in specific object. Hence we can provide the fastest speed limit providing the lower bound of the system resolution.

3. Preliminary results

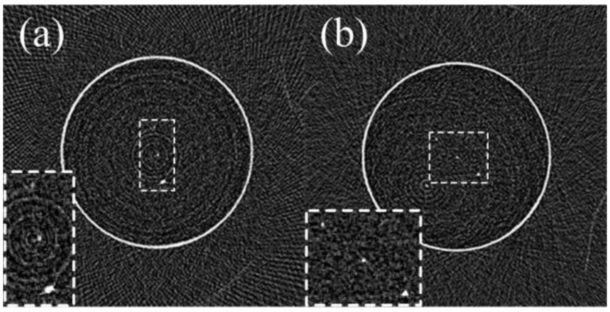

Fig. 2. Reconstructed tomographic image sample from continuous method (a), and step-and-shoot method (b). The wire tomography in the center of the image was enlarged.

The slice images acquired under the step-and-shoot and continuous scans are shown in fig. 2. Due to continuous movement of phantom, the cross-sectional image of wire acquired by continuous method was blurrier than that by the step-and-shoot method.

4. Further study

In order to investigate the relationship between acquisition time and image quality of continuous scanning, the experiment will be conducted with varying rotational speed of object. As summarized in table 2, we designed experimental conditions to maintain the same exposure by adjusting tube current. The more advanced analysis about MTF and effective aperture will be devised with detailed discussions.

Moreover, to determine the speed limit of the continuous scanning, we will investigate the typical trend of defect for NDT inspection, and characterize the lower bound of system resolution for the specific applications.

ACKNOWLEDGMENTS

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (No. 2013M2A2A9046313).

REFERENCES

[1] J. Cant, W. J. Palenstijn, G. Behiels, and J. Sijbers, Tomographic image reconstruction from continuous projections, The third international conference on image formation in X-ray computed tomography, Salt Lake City, USA, pp. 295-298, 2014.
[2] H. U. kerl, C. T. Isaza, H. Boll, S. J. Schambach, I. S. Nolte, C. Groden, and M. A. Brockmann, Evaluation of a Continuous-Rotation, High-Speed Scanning Protocol for Micro-Computed Tomography, J. Comput. Assist. Tomogr., Vol. 1, No. 4, pp. 517-523, 2011.
[3] M. R. Naeeni, R. Campagna, M. Eskandari-Ghadi, and A. A. Ardalan, Performance comparison of numerical inversion methods for Laplace and Hankel integral transforms in engineering problems, Appl. Math. Comput., 250, pp. 759-775, 2015.

Table I: Experiment conditions

	Step-and-shoot	Continuous
Number of projection	360	360
Exposure time (ms)	200	200
Current (mA)	0.6	0.6
Rotation speed (rpm)	0.1	0.83
Scan time (sec)	600	72

Table II: Further experiments

	Con A	Con B	Con C	Con D
Number of projection	360	360	360	360
Exposure time	200	200	200	100
Current	0.5	0.5	0.5	1.0
Rotation speed	0.17	0.33	0.67	1.66