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EVALUATION OF THE MODULATION TRANSFER FUNCTION OF A HIGH ENERGY X-RAY TOMOGRAPH

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Abstract

The modulation transfer function of a high energy computed tomography scanner is studied experimentally using the steel ball to estimate the performance of the system. The modulation transfer function is calculated from the edge response function in different planes in space. The modulation transfer function value is evaluated by the software designed in Matlab.

Introduction

X-ray Computed Tomography (CT) is a non-invasive technique for imaging the internal structure of solid objects and for obtaining digital information on their 3-D geometries and properties. X-ray CT is useful for a wide range of materials, such as rock, bone, ceramic, metal and soft tissue.

The modulation transfer function (MTF), which is calculated from the edge response function, is the established method of characterizing the spatial response of an imaging system. To obtain the edge response function (ERF), there are several techniques, including using a fine wire, narrow slits or an edge phantom. However, the industrial CT system was designed to explore high dense materials and it provides relatively noisy images. In addition, special software was developed to calculate the ERF, the line-spread function (LSF) and the MTF [2].

The goal of this paper is to investigate the possibility of evaluating the MTF of a high-energy CT scanner. The MTF is studied to provide precise and reliable data of spatial resolution in ZX, YZ, XY planes.

Method

Spatial resolution for the cone beam CT system is measured with the beam hardening correction according to the standard ASTM E1695-95[1]. The steel ball with the size of 33.3 mm in diameter is used as a test phantom. The ball is placed in the field of view of the CT system, and it is situated in the center of the rotation stage. 3D CT images with the beam hardening artifact are reconstructed by the raw projection data. The MTF measurement is based on a set of 3D CT images [3].

The MTF is measured in XY, YZ and ZX planes that pass through the ball center (the rotation axis is Z axis) with the beam hardening correction. The measured technique is performed as follows: in the reconstructed 3D images, the sub volume containing the steel ball is extracted. The size of the volume is larger than the diameter of the ball and equal to 1024×1024 pixels. The extracted volume of the ball is resliced on ZX, YZ, XY planes in the CT analyzer software. The resliced images are downloaded into the software designed in Matlab package. In XY plane, the edge of the steel ball in different slices is determined [1]. The edge is fitted using a circle. Thus, the center of the steel ball is Xcenter, Ycenter and Zcenter. In YZ and ZX planes, the same method to find the center of the steel ball and the maximum diameter of the fitting circle is used. The ERF is calculated automatically. To obtain the LSF and MTF, the bottom “Sum of curves” is used. The software for MTF calculation is presented in Fig. 1.

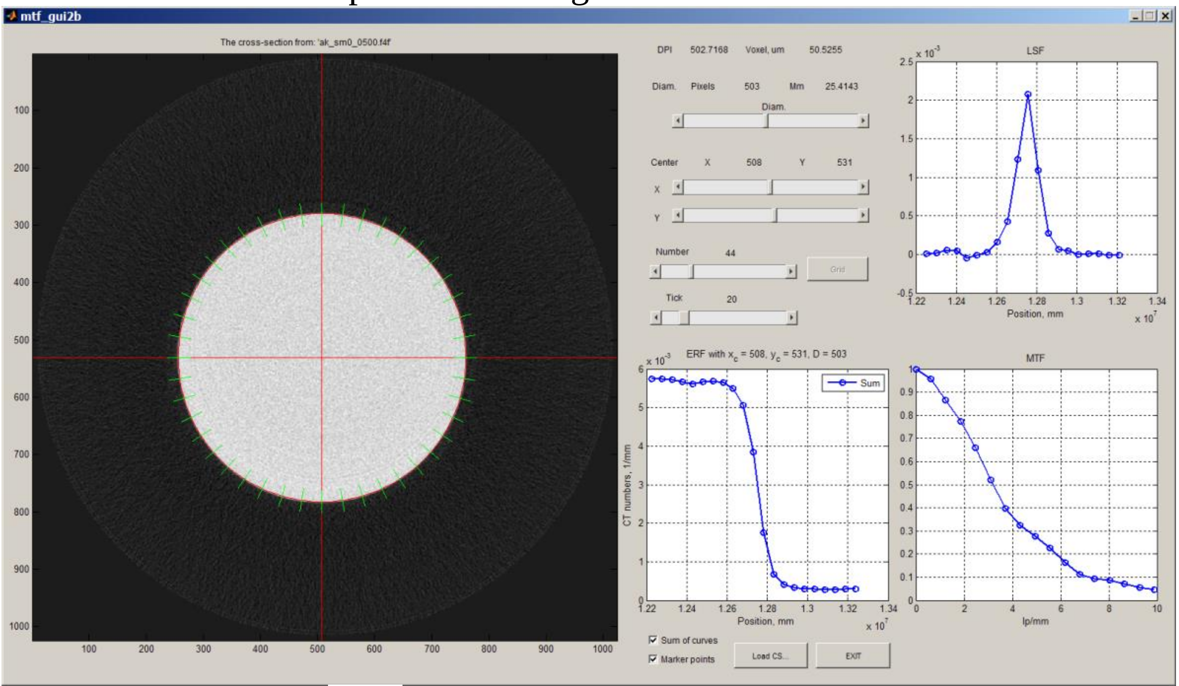


Fig. 1 Software for the MTF calculation

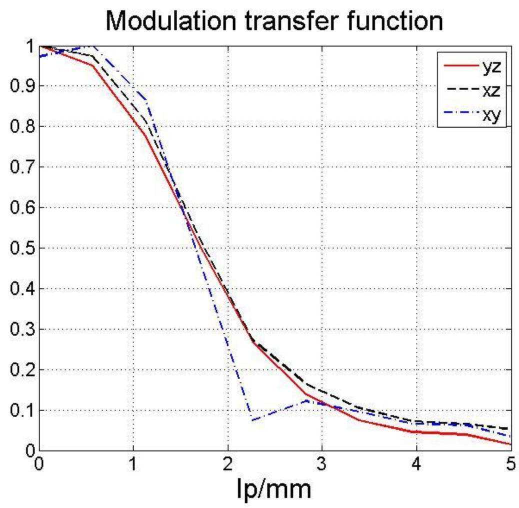
Experimental setup

The experiment is performed with a 450 kV cone beam micro-CT system. The system was developed and built by the scientists from Tomsk Polytechnic University. The main components of the system are: 16-bit TFT detector, an X-ray tube and a rotation stage. The TFT (Perkin Elmer, USA) compact 2048×2048 200 μm-pixel array and the conversion screen are integral columnar CsI. The X-ray tube (Comet, Switzerland) has a 0.4 or 1mm focal spot.

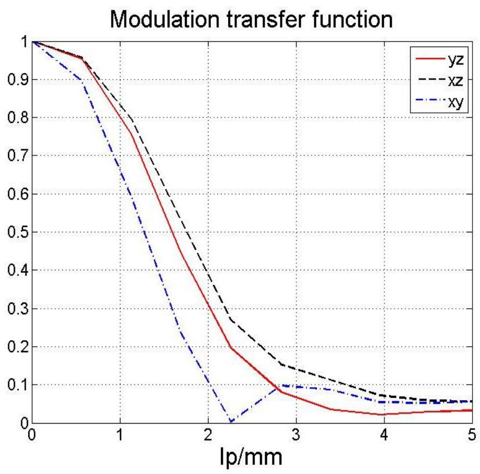
Results

Three different series of measurements were carried out in order to evaluate the MTF. Three scans were performed under 300 kV, 300 kV, 400 kV using Cu filters. The thickness of the filters was equal to 0.5, 3 and 4 mm, respectively. The MTF curves obtained in measurements are illustrated in Fig. 2. The data is represented as a mean value.

a



b



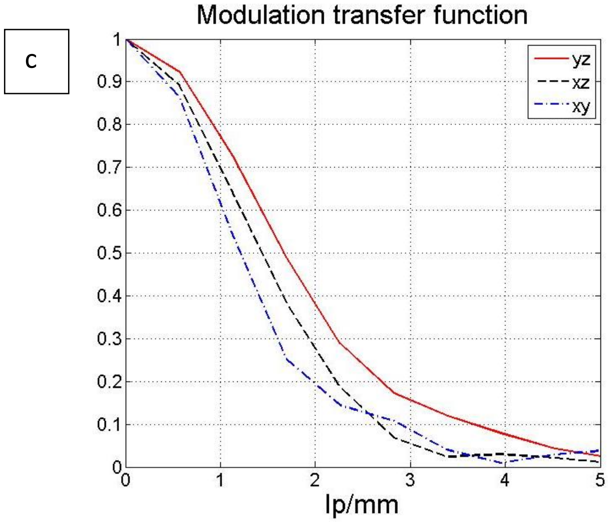


Fig. 2 Modulation transfer function curves of cone beam CT: a is for 300 kV with 0.5 mm Cu filter, b is for 300 kV with 3mm Cu filter, c is for 400 kV with 4 mm Cu filter

Comparison of the MTF in different measurements is shown in Fig. 3.

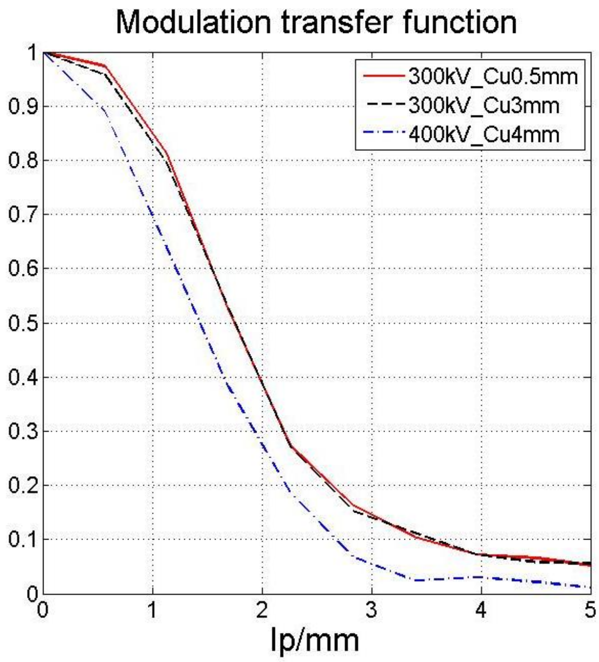


Fig. 3 MTF in different measurements

Summary

In this paper, the MTF of the high energy computed tomography system was calculated using the software designed in Matlab package. The analysis of the curves showed that at 20% of the conrast, MTF varies from 2.5 to 3.5 lp/mm for different measurements (see Fig. 3). Thus, the best MTF is 3.5 lp/mm for the voxel size of 55 μm obtained at 300 kV with 0.5 mm Cu filter.

The spatial resolution of the X-ray tomograph is equal to 140 µm.

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RESEARCH AND MANUFACTURE OF SAMPLES FOR THE PRACTICAL TEST IN METHODS OF NONDESTRUCTIVE INSPECTION

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Today, with the growing demands for quality, reliability, safety and remaining life prediction of components, non-destructive testing personnel are entrusted with more responsibility than ever. NDT experts performing test, undergo rigorous training and are required to pass certification examinations as per the schemes stipulated by the national or international standards prevailing in the respective country. For renewal or revalidation of a certificate, which is valid only for a limited period, it becomes necessary for NDT personnel to keep their NDT knowledge up to date. In process of certification NDT specialists there are used control samples that are made from advance and certain material with different types of defects. The variety of test samples used in the inspection, their duplication and complexity create disorder in the selection of the required sample. To solve this problem, control samples are classified into the following groups.

Classification of defects

By localization of defects:

- with surface defects;
- with subsurface defects.