SPATIAL RESOLUTION OF NEUTRON RADIOGRAPHY SYSTEM BY MONTE CARLO SIMULATION

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ABSTRACT

A simulation of neutron imaging was performed to investigate the spatial resolution properties of a neutron radiography system. A cadmium plate was imaged by neutrons using a plane radiographic detector placed behind the plate. The detector was evoked by the radiographic tally facility of a Monte Carlo simulation codes. Radiograph of the cadmium plate was obtained and the edge spread function data were extracted from it. Modulation transfer function which gives the spatial resolution properties was calculated from the edge spread function data.

Keywords: neutron radiography, Monte Carlo simulation, spatial resolution.

INTRODUCTION

We are studying imaging properties of a neutron radiography system available at the Malaysia Nuclear Agency in order to enhance the output image. As a part of the study we simulate the system via MCNP [1] codes to study its spatial resolution properties. The work was performed using simple model without going into detail modeling and geometry to get representative data of the problem. Also, methods, form of data, its analysis and method of calculation of the spatial resolution property parameters need to be determined from the work.

METHOD

A cadmium plate of 1.0 mm thick with one of its corners placed at the origin of rectangular coordinate system is radiographed by thermal neutron beam [2]. The neutron beam is 3 cm in radius with the neutrons moving in the $-z$ direction and coming from a disk source at position $z = 20$ cm. The neutrons diverge at 5 degrees about the $-z$ direction. A radiography tally of MCNP (FIR5 card) is set up at position (0, 0, –1 cm) with grid of size –0.25 cm to 0.25 cm in the xy plane and pixel size of 25×25 microns. Thus, there were 200×200 pixels on the radiograph.

About 520,000 neutrons were transported so that relative error of the flux in each pixel is within 5% with simulation time of 420 minutes using a dual core Intel based PC with Windows Vista operating system.

The edge spread function data were extracted from the 'mctal' file of MCNP using the 'gridconv' utility [1]. The edge spread function was differentiated to get the line spread function [3]. The modulation transfer function which gives the spatial resolution properties was calculated from the edge spread function data via fast Fourier transformation [4].

RESULTS

Figure 1 is the contour plot of the cadmium plate produced by MCNP plotter with the 'noline' option. The shadings represent ranges of neutron flux in units of per cm^2 per particle of each pixel. The lower right part of the contour plot corresponds with the position where the cadmium plate was placed. The figure confirms that there is lower neutron flux behind the cadmium plate and higher flux in unobstructed region. The figure also shows blurring of the edges of the plate.

Figure 2 is surface plot of the radiograph. This plot was produced from the same data as of Figure 1. The vertical axis is the neutron flux (per cm^2 per particle) and the horizontal base is the radiographic grid coordinates (cm). Again, the figure confirms that there is lower neutron flux behind the cadmium plate and higher flux in unobstructed region. Blurring of edges of the plate can be seen.

Figure 3 is an edge spread function extracted from the data. This is the usual sigmoid curve showing the unsharpness of the imaging system. By differentiating the edge spread function, we obtained the line spread function, Figure 4. The line spread function is Fourier transformed to give the modulation transfer function, Figure 5.
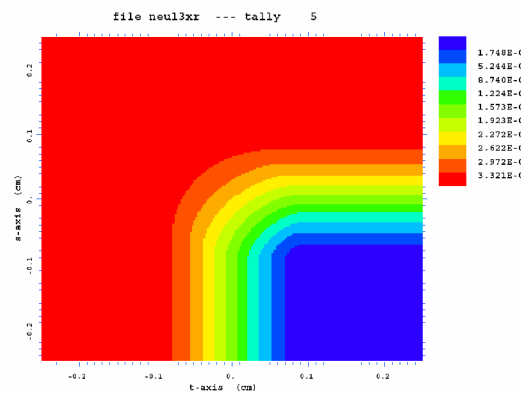

Figure 1: The radiograph obtained from the simulation using the contour plot of the MCNP with 'noline' option. The grid size was from -0.25 cm to 0.25 cm in both the *x* and *y* axes, giving the grid of 0.5 cm × 0.5 cm. The legends give the neutron flux (per cm^2 per particle).
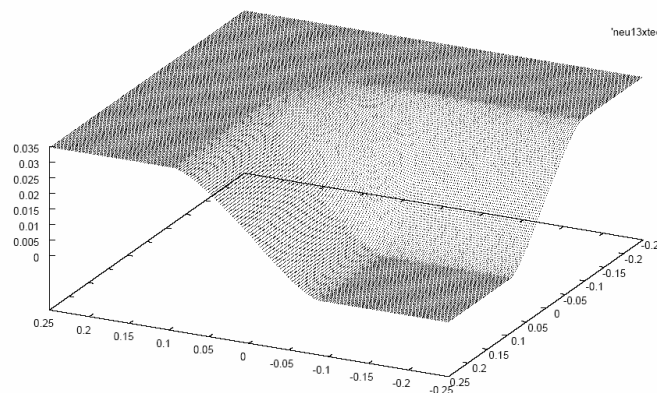

Figure 2. Numerical data of the contour plot were displayed as a surface plot. The vertical axis is the neutron flux (per cm^2 per particle). The horizontal base is the radiographic grid in cm.
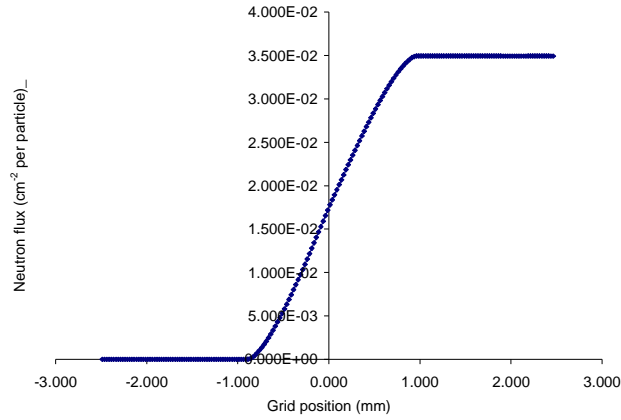
Figure 3. The flux profile across the edge of the cadmium plate image gives the edge spread function of the simulated neutron radiography system. The edge spread function data were extracted from the edge profile of the radiograph.
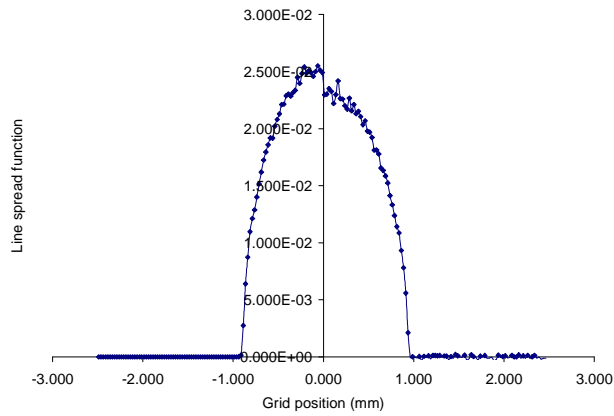

Figure 4. The line spread function of the simulated neutron radiography system. Curve of FIGURE 3 was differentiated to get this line spread function.
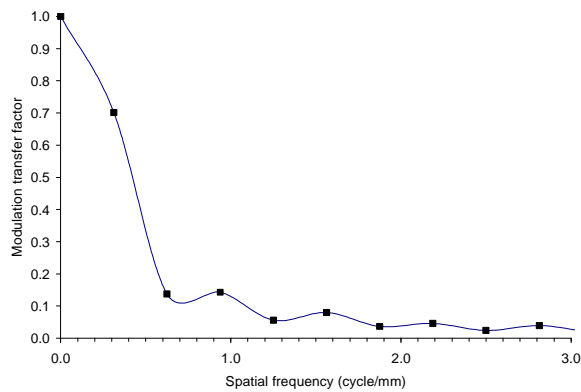

Figure 5. Modulation transfer function of the simulated neutron radiography system. The line spread function was fast Fourier transformed to give the modulation transfer function.

DISCUSSION

The spatial resolution of the neutron radiography system as given by the modulation transfer function was found comparable with other published results [5]. The MTF drops rapidly with spatial frequency. At MTF of 20% the spatial frequency is about 0.6 cycle-/mm, Figure 5, comparable to typical value. Theoretically the line spread function is symmetric about the *y* axis, but Figure 4 shows it is not in our case. We suspect that our simulation parameters were too ideal to mimic the real system. Our plan is to get this simulation working and later perform the real experimental work from which meaningful comparison can be made. We plan to use cadmium slit as other way to get the MTF via the line spread function technique [3].

CONCLUSION

Spatial resolution properties of a neutron radiography system were studied by Monte Carlo simulation. The edge spread function technique used in the simulation gave comparable modulation transfer function indicating the system modeled was adequate. Further work is needed to verify the model through real experiments.

ACKNOWLEDGMENTS

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