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Samples to determine the resolution of neutron radiography and tomography

A.P. Kaestner[a,*], Z. Kis[b], M.J. Radebe[c], D. Mannes[a], J. Hovind[a], C. Grünzweig[a], N. Kardjilov[d], E.H. Lehmann[a]

[a]*Laboratory for Neutron Scattering and Imaging, Paul Scherrer Institut, CH-5232 Villigen – PSI, Switzerland*
[b]*Nuclear Analysis and Radiography Department, Centre for Energy Research, Hungarian Academy of Sciences, H-1525 Budapest 114, P.O. Box 49, Hungary.*
[c]*Radiation Science, NECSA, P1500, P.O Box 582, Pretoria, 0001, Republic of South Africa*
[d]*Institute Applied Materials, Helmholtz-Zentrum Berlin für Materialien und Energie, Lise-Meitner-Campus, Hahn-Meitner-Platz 1, D-14109 Berlin, Germany*

Abstract

Knowing the resolution and effective pixel size of an imaging system is essential for dimensional and quantitative measurements. A collection of test devices was developed for neutron imaging that can be used to quantify pixel and voxel size, resolution of the imaging system, and beam divergence. The first set of devices is intended for measurements with radiographs using test patterns or an absorbing edge. For tomography, Al vials were filled with Ti spheres of increasing dimensions in each vial. Ti was chosen since it provides sufficient contrast while the transmission is still guaranteed. The first resolution criterion was to determine from which vial that the spheres can be uniquely identified as spheres. More complex analysis would involve measuring the volume of the spheres or even to compute the edge spread function analogous to the method with the knife-edge for radiographs. For the edge analysis, a larger Ti sphere was considered. Using a sphere for the edge spread function analysis allowed for determination of the resolution in any direction. Images acquired using the different test items are included and methods to perform the analysis required to quantify the resolution from the images are proposed.

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1. Introduction

The resolution that can be achieved with a given imaging setup is a key parameter when the performance of the setup is described. The availability of a simple and efficient method to measure the resolution is of high importance for neutron imaging, in particular, as most installations are camera based with a variable field of view. This means that the resolution changes every time the field of view is changed and when the detector system is changed. The focusing procedure also requires feedback from the image sharpness. Different approaches have been proposed to determine

* Corresponding author. Tel.: +41-56-310-4286 ; fax: +41-56-310-3131.
E-mail address: anders.kaestner@psi.ch

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the resolution using X-rays some have even been standardized, e.g. the duplex wire method (ASTM, Standard No. D 2002-2015, 2015) and also detector characterization (ASTM, Standard No. E 2597M-2014, 2014). The most direct and rapid way to determine the resolution range is by using test patterns like line pairs or the Siemens star. We have produced test items using laser ablation to create these test patterns on Gd sputtered glass. The items are made with different dimensions and patterns. A different method to determine the resolution from radiographs is to use the edge response from a sharp edge (knife-edge) of a strongly absorbing material. Our knife-edge item is made of a Gd sheet mounted in an Al frame that makes the positioning easier. This item has a horizontal and vertical edge that can be used to determine the resolution in two directions. The beam divergence can also be determined using this item when it is placed at different distances from the detector. At Paul Scherrer Institut we have designed patterns based on the Siemens star as a tool to quickly observe and measure the current resolution of a neutron radiograph (Grünzweig et al., 2007).

Quantifying the resolution in computed tomography increases the complexity of the test device design. The third dimension adds the criteria that the sample must be able to transmit the radiation from all views of the tomography scan. A test device designed as a disc has been introduced for X-ray based CT in ASTM, Standard No. E 1695–1995 (2013). In this paper we propose two new test devices using spheres to determine the resolution. In collaboration with the International Atomic Energy Agency (IAEA) a set of samples for computed tomography was designed and will be evaluated in a round robin test cycle. In this paper we describe different samples with the purpose to determine the spatial resolution for radiography and computed tomography with neutrons.

2. Sample descriptions

2.1. Radiography

Radiography is the basic acquisition mode for a neutron-imaging instrument. The radiographs are either used directly or as raw information for more complex methods such as computed tomography, grating interferometry imaging, spectral imaging etc. The sharpness of the computed images produced by all these methods depends on the sharpness of the original radiographs. Therefore, it is of high importance to have an easy method to determine the resolution of the radiographs such that it is possible to measure the resolution conveniently for every change in experimental configuration. This is particularly important for camera based instruments with variable field of view (FOV) as the camera is refocused every time a new FOV is needed. We propose two different test devices to determine the resolution of a radiograph; 1) test patterns that indicate the resolution directly, Fig. 1, and 2) items to determine the sharpness of a high contrast edge, Fig. 2.

The large test pattern shown in Fig. 1 is made of a 5 μm Gd layer sputtered on a transparent glass substrate. This makes it possible to use the test pattern also with visible light for the first focusing, before being exposed to neutron radiation. The device contains four different feature types to the determine the spatial resolution. Siemens stars located at different places to verify if the resolution depends on the position on the detector. Line patterns with different line spacings from 0.010 mm to 1.0 mm were placed vertically and horizontally, Table 1.

Line width [mm]	0.01	0.025	0.05	0.75	0.1	0.2	0.3	0.5	1.0
Spatial frequency [lp/mm]	50	20	10	6.67	5	2.5	1.67	1	0.5

Table 1. Line widths present in the line patterns and their spatial frequencies.

A slanted box (tilt angle 3°) was included for measurements of the modulation transfer function (MTF). Finally, there are also line grids that can be used to measure the pixel size for the chosen FOV. There are grids with 1 mm and 10 mm line spacing. The lines in the grids can furthermore be used to identify lens distortion and provide information for a distortion correction procedure.

The second type of device is made of a Gd sheet with two polished edges mounted in a frame for convenient positioning. It provides an estimate of the resolution by means of an image analysis step to provide the resolution. The analysis steps for this test device are to determine the pixel size (variable if the FOV can be changed) and to measure the width of the edge spread function or the modulation transfer function (Boreman, 2001). This device can also be used to estimate the penumbra blurring at different distances from the detector. The procedure for this kind of