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Recent progress of radiography and tomography at the energy-resolved neutron imaging system RADEN

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Abstract

We have performed neutron radiography and tomography using a CCD camera-type detector for some test samples at RADEN. The current spatial resolution for neutron radiography is estimated to about 350 μm in the largest field-of-view of 300 × 300 mm^2 and 100 μm in the field-of-view of 60 × 60 mm^2. It is thought that the latter spatial resolution is strongly affected by the image blur in the scintillator screen. In the case of neutron tomography, the current spatial resolution is estimated to be better than 0.5 mm using an iron and aluminum test sample. Furthermore, we have performed neutron tomography for a cast aluminum product. As a result, small blowholes are found in the center of the product. This demonstrates the importance of non-destructive testing by neutron radiography and tomography for industrial products.

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Keywords: *Neutron radiography; Neutron tomography; RADEN; Non-destructive testing*

1. Introduction

RADEN at J-PARC MLF is the world's first neutron imaging system dedicated to not only the energy-resolved imaging taking full advantage of the pulsed neutron source but also conventional neutron radiography and

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tomography. One can select the beam size, beam divergence (L/D ratio), neutron flux and wavelength appropriate for the purpose of each experiment by optimizing beam parameters such as shutter size, collimator size, and chopper phase (Shinohara et al. 2016). Since the available beam size is up to 300 × 300 mm^2 which is the largest beam size at J-PARC MLF, it is possible to obtain the transmission image of large objects in a single measurement with the large field of view (FOV). In addition, several highly-effective 2D detectors (e.g., camera-type detector and counting-type detector (Parker et al. 2013, Uno et al. 2013, Satoh et al. 2015)) were prepared and are being developed. Therefore, it is possible to visualize material information efficiently by combining the large FOV with such 2D detectors at RADEN. In this study, we report the current status of neutron radiography and tomography using the camera-type detector and present a demonstration carried out on an industrial product at RADEN.

2. Experimental

The layout of the detection system used in the present study is shown in Fig. 1. This system consists of a camera-type detector and a small rotary stage. Neutrons which penetrate a sample are converted to green light by the ^{6}LiF + ZnS scintillator screen of area 300 × 300 mm^2 and 0.1 mm thickness and focused on the camera sensor by a high reflective mirror. In this study, we adopted a large area CCD camera, the ANDOR iKON-L (Andor Technology Ltd). This CCD camera provides 16 bit images, and its sensor (2048 × 2048 active pixels) is cooled to -100 °C with a Peltier module and coolant circulation to suppress dark current noise. It is also fixed to a vertical moving stage. The FOV can be freely adjusted in the range 50 × 50 mm^2 to 300 × 300 mm^2 using different prime lenses, such as 50 mm f/1.4, 105 mm f/2.8 and 150 mm f/2.8 with the maximum aperture, and adjusting the vertical position of the camera. These detector components are surrounded by thick lead plates and boron rubber sheets to protect the CCD sensor and reduce undesirable noise due to scattered neutrons and γ-ray irradiation. In addition, the whole detector box is covered with matt black aluminum plates and maltoprene sponge to secure against leakage. As for neutron tomography, both the camera-type detector and the rotary stage can be controlled simultaneously using the software framework IROHA of J-PARC MLF (Nakatani et al. 2015). J-PARC consists of the multi-purpose facilities and neutron intensity changes during data acquisition due to accelerator trips, proton beam sharing and so on. Thus, the transmission image data is saved and the rotary stage turns to the next condition only when the number of proton pulses injected to neutron target satisfies a set point estimated from the camera exposure time. In this way, a projection image that is not influenced by drift of the pulsed neutron source can be acquired automatically. In the present study, each projection image is obtained by rotating the sample stage from -90º to +90º by 180 steps, and normalized with neutron beam intensity after subtracting by dark current noise of the CCD camera. The reconstruction of the 3D image of the sample by the filtered back projection (FBP) method and analysis of its computed tomograms are performed through the visualization software VG studio MAX (Volume Graphics GmbH).

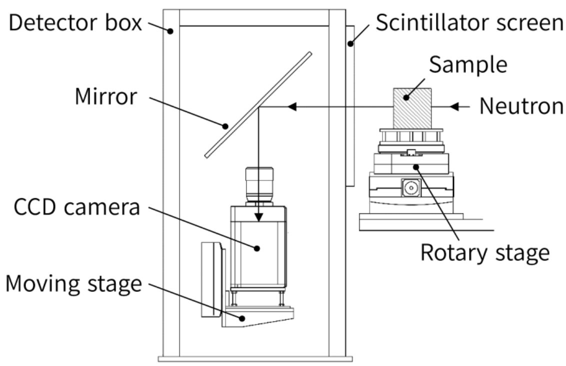

Fig. 1. Schematic illustration of the CCD camera-type detection system at RADEN.