# A Feasibility Study of Fast-Neutron Transmission and Tomography for a Thick Steel Box at the NECTAR Facility

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## 1. Introduction

Fast-neutron imaging technique is a non-destructive testing method similar to the well-known X-ray and gamma- rays imaging techniques. Further fast-neutron imaging technique is really attractive for large objects in industrial applications, because of its penetration capability [1-3]. Especially, one of its main characteristics is discrimination abilities in complexing substances mixed with high Z and low Z materials. Light elements in combination with heavier elements are difficult to detect and image with X-rays since they provide very little contrast [4, 5]. The cross section for neutrons depends on the specific nucleus and its nuclear structure.

The aim of this work is to determine the potentials of fast-neutron transmission and tomography imaging techniques for larger capacity objects as industrial application. And also this work would be the study of the attenuation of the beam intensity as the comparison of the neutron penetration capabilities with fast neutrons above 1 MeV.

This work has been carried out at the NECTAR ((NEutron Computed Tomography And Radiography) facility located at the FRM II nuclear research reactor, Technical University of Munich, Germany. The NECTAR is a facility offering fission neutron 2-D transmission and 3-D tomography imaging in an official user program.

## 2. Experimental

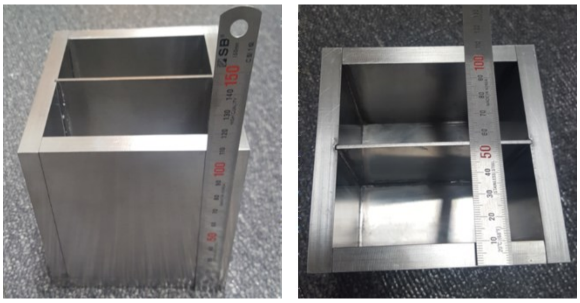
For this work, the investigation has been carried out at NECTAR having averaged 1.8 MeV neutron energy. The FRM II nuclear research reactor is under the continuous operation of 20 MW. The total neutron yield of the FRM II reactor is $10^{13}$ $cm^{-2}$ $s^{-1}$. The fast-neutron flux at the device position was estimated to be about $10^{7}$ $cm^{-2}$ $s^{-1}$.

We have used existing fast-neutron imaging device with a standard scintillator at the facility. In the work, objects with larger capacity such as a large steel box and HV (154KV) power cable were used as application sample.

First, in order to get 2-D transmission image, a steel box filled with water and wedges made of PE and aluminum, and HV power cable as shown in Fig. 1 was used as test samples to be exposed by the fast neutron beam and placed directly in contact with the screen of the device as shown in Fig. 2. The transmission measurement was separately taken at 0 and 90 degrees. The exposure time was 60 second. The result of images obtained at 0 and 90 degrees are shown in below.

Next, 3-D tomography images have also taken at the same position and experimental conditions. The exposure time was also 60 second. The object was rotated with a full 360 degree so as to obtain 1000 images.

Thick Steel Box



Mass : 4.3 kg
Size : 11 cm (W) x 11 cm (L) x 11cm (H) x 1 cm (T)
Chemical Composition : SUS304

Fig. 1. Photograph of a steel box

Fig. 2. Photograph of installed samples on the imaging device

## 3. Results

For this work a thick steel box filled with water, and wedges made of aluminum and PE, and a cylindrical HV power cable were used as application samples to be exposed by the fast neutron beam and placed directly in contact with the screen of the device.

The steel box and HV power cable for fast-neutron transmission imaging was exposed to 60 seconds. The resulting images of the steel box with HV power cable taken at 0 and 90 degrees are shown in Fig. 3.

It is just the raw image without any image processing nor flat correction or artefact removal. It is also shown that neutrons are attenuated by low-Z elements such as aluminum, and PE, but they penetrate high-Z materials such as steel.

| Fast-neutron 2-D image at 0 degree | Fast-neutron 2-D image at 90 degree |
|---|---|

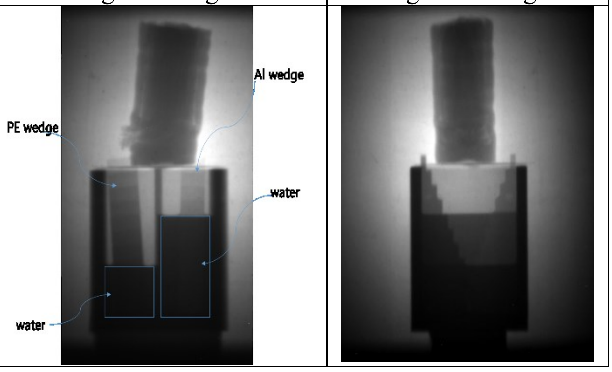
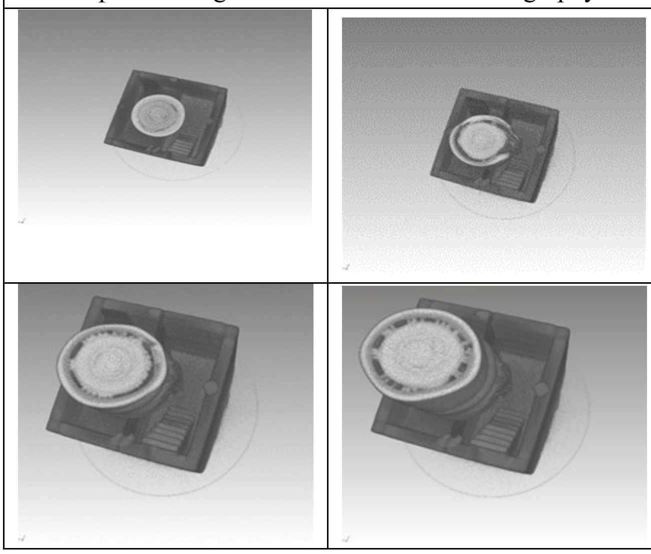



Fig. 3. Results of fast-neutron transmission images obtained at 0 and 90 degress

On the other hand, in the 3-D tomography imaging, the captured results of the fast-neutron 3-D tomography image after reconstructed for 1000 images are shown in Fig.4.

| Captured images of fast-neutron 3-D tomography |
|---|



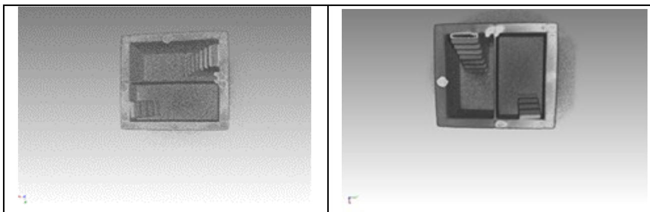


Fig.4. Captured results of fast-neutron 3-D tomography image after reconstructed

## 4. Conclusions

In this work, a feasibility study of fast-neutron 2-D transmission and 3-D tomography imaging has performed with averaged 1.8 MeV neutron energy at NECTAR. We have carried out the study using a scintillator based system with a CCD camera.

The results show that it is possible to confirm the potentials of fast-neutron 2-D transmission and 3-D tomography imaging of the thick steel box. Due to the short exposure time, and a large VOD, the spatial resolution of the digital images for the two samples is obviously not very good. Also the contrast of the presented image appears rather moderate.

It is concluded that a longer exposure time for 3-D tomography and the focused VOD can improve those considerably.

## ACKNOWLEDGMENTS

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