Digital Neutron Radiography for Identification of Archaeology and Cultural Heritage Objects in Tehran Research Reactor

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Abstract
Neutron radiography is an advanced radiography technique in non-destructive testing of different specimens including the archaeology and cultural heritage objects. The neuron imaging facility of Tehran research reactor has recently been updated and effectively used for different objects. In this research, an art pieces is used for neutron radiography. Digital neutron radiography has been carried out. The results showed that the new digital radiography system can effectively be used for the cultural heritage objects.
Keywords: Neutron Radiography, Cultural Heritage, Digital Imaging, Tehran Research Reactor, NonDestructive Testing.

Introduction
Neutron radiography (NR) is a useful technique in non-destructive testing (NDT) of archaeology and cultural heritage objects. NR is a radiography technique and complementary to X and gamma radiography. In this method, neutrons are attenuated after passing through the material and interacting with the test sample, in proportion to the cross-section of neutron interaction with the nuclei and the thickness of material according to relation 1:

$$\frac{I}{I_0} = \exp\left(\int_{dt \in T} -\Sigma \, dt\right) \qquad (1)$$

where I_0 and I are the primary and secondary neutron beam intensities, respectively, Σ is the macroscopic absorption cross-section of the material for the neutrons and t is the thickness of the material.

The amount of radiation reaching to detector contains valuable information from inside the test material, which by detecting and converting into an image, the structural details of the material can be realized. The neutron imaging can be used effectively for the radiography of light elements such as H-containing materials [1-2].

A new NR beam line has recently been built at the Tehran Research Reactor (TRR) and both film and digital radiography capability has been provided to the neutron imaging system in order to expand the applications of NR [3]. The examination and characterization of internal structure and composition can be difficult task, in particular for cultural heritage objects. With NR, it is possible to visualize hydrogen containing materials inside metal artefacts much better than with X-rays.

Experimental setup
The new digital imaging at TRRIF (Tehran Research Reactor Imaging Facility) uses a periscopic arrangement for decreasing of neutron impact to the digital camera, which can be destructive for CCD or CMOS part of camera. The typical arrangement can be seen in Fig. 1. For NR, the sample was fixed on the steady stage between neutron beam and scintillator. For neutron CT imaging purposes, the stage must be rotated.

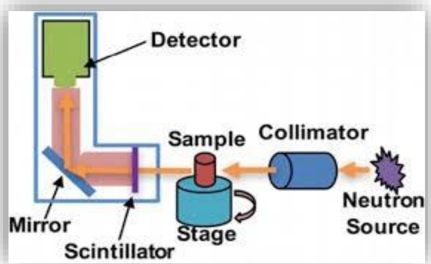

Figure 1. Typical periscopic setup for digital neutron radiography: electronic parts of digital camera does not face with neutron beam.

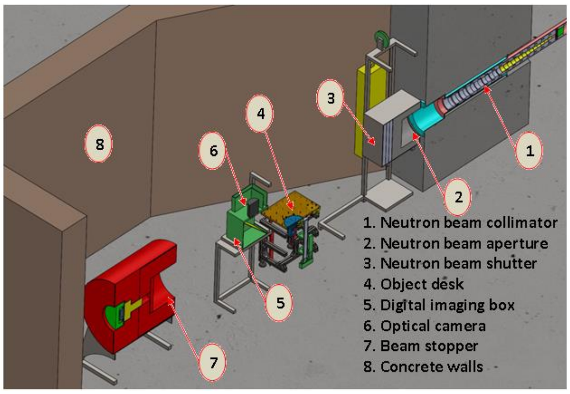

Figure 2. Typical setup of neutron radiography in TRR: The collimator, shutter, object desk, digital camera, beam-stopper and concrete walls can be seen.

In this research, a bronze statue has been radiographed by means of new neutron beam line of TRR. The object was a staute made from Bronze that is shown in Fig.3. It is a statute of ancient military man made from bronze.

The digital neutron radiography technique was used by the digital imaging system.The reactor thermal power was setup to 4 MWatt and imaging has been carried out.

Figure 3.Bronze statue in the front of neutron imaging detector

The digital radiography images were obtained and saved in digital Tiff format, which is a loss-less format. The bit-depth of images was 16 bits and can show up to 65536 gray level. The digital camera is an ultra-low noise camera and uses an internal cooling system for noise reduction.

The digital neutron radiography technique was used by the digital imaging system. The image was obtained and saved in digital Tiff format. Digital image processing was implemented for enhancing the image. The unprocessed (raw) image is shown in Fig. 4. Different noises and spots can be seen in the image, resulting from interaction of scattered gamma rays and neutrons with digital camera chip. These different noises have to be corrected for acquiring the better radiography images. Also intensity inhomogeneity in the beam line has to be corrected.

Results and discussion

For cancelling the noises and speckles, an “outlier” filter has been implemented. In addition the raw image has been normalized and corrected by the “dark-beam” and “open-beam” calibration images.

The corrected final two dimensional image is shown in Fig. 5. The defect regions is completely revealed and can be detected clearly. The defects are observeable in the right leg and also in the head and near the left hand of the neutron radiograph.

Conclusions

The initial neutron radiography images suffer from different noises and intensity inhomogeneity. Different correction method have been applied to the raw neutron digital image. The results showed that the new system can be used effectively for the neutron radiography of cultural heritage objects and can reveal different defects and designed in the art pieces.

Figure 4.Raw digital NR image of the statue

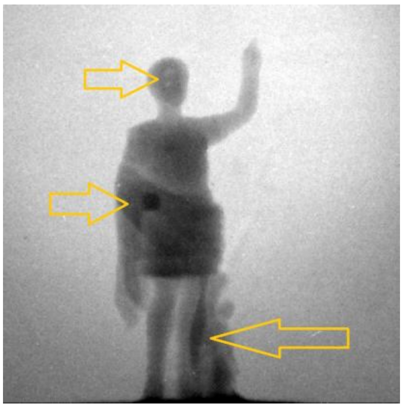

Figure 5.Digital NR image of the statue after pre-processing

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