International Journal of Multidisciplinary Research and Development
Online ISSN: 2349-4182, Print ISSN: 2349-5979; Impact Factor: RJIF 5.72
Received: 18-10-2019; Accepted: 19-11-2019
www.allsubjectjournal.com
Volume 6; Issue 12; December 2019; Page No. 75-78

Conceptual designing of neutron radiography system in order reorganization of effective parameters in image quality and optimization of them for nuclear and industrial laboratory applications in Afghanistan by using mont-carlo calculation cod-MCNPX

Dr. Dawod Mirzaee[1*], Rajab-Ali Khavari[2], Ali Safaee[3]
[1] Department of Nuclear and Atomic Physics, Faculty of Physics, Kabul University, Kabul, Afghanistan
[2] Department of Physics and Electronics, Faculty of Physics, Kabul University, Kabul, Afghanistan
[3] Faculty of Physics, Esfahan University, Esfahan, Iran

Abstract

Destroying of diffracted neutrons component or separating of them from passed neutrons through the sample is one of the most important factors in resolution and quality of images in neutron radiography. Neutrons diffraction will create distortion and darkness at images. We introduce an algorithm in order to correction of neutron diffraction in radio graphical images. For this reason, we use Mont-carol code MNCPX which have specific ability to calculation neutron space distribution on detector screen. Since, component distribution of neutron diffraction influenced by different factors such as type of material, thickness of them and distance of sample from the detector, we simulated a sample of water with different thickness and distance from detector screen and applied a correction algorithm of distribution function of neutron diffraction on total neutron distribution on the detector screen. The obtained result shows that image clarity and resolution of them will significantly improve by application of diffraction function distribution depend on sample thickness and sample distance from detector. We will try to use this photography method at nuclear physics laboratory of physics faculty of Kabul University, and to find a way to apply them in airport station control section and land border control section and etc.

Keywords: neutron radiography, resolution, point spread function PSF, Mont-Carlo calculating code MCNPX, nuclear laboratory of Kabul University

Introduction

Recently used different methods to recognition of inner characteristics of material without distortion of them, which called non-destructive tsetse. X-ray radiation mostly used for non-destructive tsetse in medical area. Neutron photography is one of the nearly modern methods which used in this field. Unlike the X-ray, Neutron radiography can broadly used in different industry such as metallurgy, has some advantages in compression with X-ray radiography. Neutron beam can easily penetrate in metals and it has more influence at light elements such as Hydrogen, Latium and Bore [1]. At this method, a neutron beams radiated through the sample under consideration; as a result, effect of passed neutrons on the photograph film or location-sensitive detector, will record an image of the sample. Neutron radiography system generally consist of a paralleled neutron beam source, a sample under consideration and a detection system [2, 3].

The emitted neutrons from a source are directed to the object studded and interact with the specimen by a parallel system; the detector at the back of the specimen will record all the passed neutrons whether interact with specimen or not. The detector plan is mainly placed perpendicular to the beam and represented as a tow-dimensional array of pixels. The neutron fluxes, after interaction, can be divided into the flowing components:

- Collided flux; part of diffracted neutrons after interaction within the sample, will reach he detector.
- Uncollided flux; part of penetrated neutrons to the sample, passed through them and reach the detector without any interaction.
- Unmodified flux; which contains all the neutrons that not penetrated the sample at all and reached the detector plane (i.e., the neutrons that come from the parallel system output directly to the detector plane) [5].

The view of these interaction models for a parallel neutron beam is shown in figure 1. In neutron radiography system, thermal and cold neutrons are usually used because the most of the materials have a high attenuation coefficient for low – energy neutrons, therefore not only damping but rather detection sensitive for low-energy neutron detectors is high and this permitted using the fine detectors with higher resolution [6].

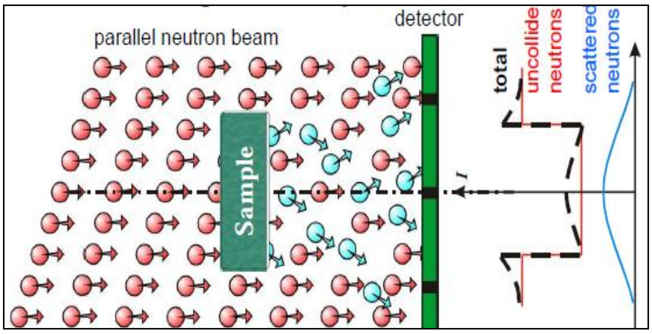


Fig 1: the interaction model of parallel neutron beam with a sample under investigation

Since cross- sectional area of the hydrogen dispersion is used for thermal neutron from order ($\sigma_s = 80.26\ barn$), diffracted neutron component from hydrogenise materials such as polietelen, PMMA, oil, water and etc, in radiographic pictures is cincedirly high, so we can't ignore it. The neutron scattering power for materials is highly dependent on the attenuation coefficient, sample size and material thickness, the distance between the sample and the detector [7]. The neutron scattering power for materials is highly dependent on the attenuation coefficient, sample size and material thickness, the distance between the sample and the detector [7]. Neutron flexor intensity is one of the most important parameters in neutron imaging because it has the least impact on the time of exposure or actual signal-to-noise ratio for radiograph quality, as well as detection limits and statistical errors with signal-to-noise ratios [4]. On the other hand, the main neutron flux depends on the parallelism and the field of view of the neutron, and the imaging plates show sample information with high resolution. In the two-dimensional radiographic system, many methods and algorithms for image correction have been proposed, taking into account the factors involved in neutron scattering and subsequent distortions in neutron radiography imaging [5]. In this research due to the importance of neutron radiography in the qualitative and quantitative detection of materials as well as its many applications in industry, enhancing the security of the country as well as the Kabul University Nuclear Physics Laboratory, neutron radiography has been used based on a scatter correction method and the analytical function called Point Spread Function (PSF) was studied in the discrete space of the neutron source and the detector plate. This function represents the sum of the neutron components, including impact and non-impact neutrons. The distribution of neutrons depends only on the impact component of the PSF function, which is defined as the point scattering function (PScF) [1]. Since scattering takes place only in the sample area, the scattering effect will greatly depend on the location. This neutron scattering distribution, as stated, depends on the sample material, its thickness, as well as the sample-to-detector distance [7] and [3]. Considering these factors by subtracting the point scattering function of each pixel of the detection plate, an algorithm for image correction in neutron radiography can be obtained.

Theory and Methodology

The effect of neutron scattering on different materials with different characteristics can be achieved by laboratory experiments or simulation methods using standard cods. Simulation methods can in many ways outperform experimental laboratory methods, including their dependence on location, time, and specific measurement constraints. The method used here is the Monte Carlo simulation, which is discussed in more detail below.

Monte Carlo simulation

Using the Monte Carlo MCNPX computational code capabilities, the effects of neutron scattering on neutron X-ray images can be calculated and simulated. The neutron source used to perform this simulation is ^{252} Cf. since these tests require a parallel thermal neutron beam, parallelization has been used for this purpose [7]. The neutrons ejected from the parallel aperture collide with the water sample, and The neutrons are recorded on a pixel-detecting plate by means of a tally radiography. As shown in Figure (2), the problem geometry is modeled for computing point flattening and point scattering functions in MCNPX code [3]. Tally radiography has the capability to obtain scattered neutrons on the detector plate in addition to obtaining the overall distribution of neutrons.

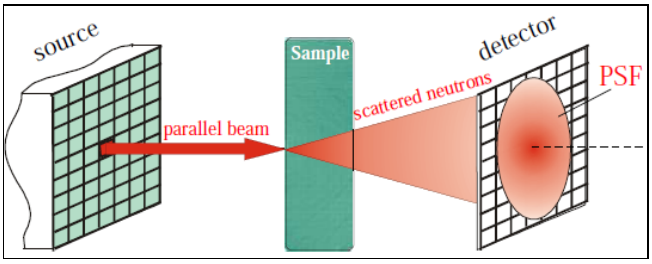


Fig 2: Problem Geometry Modeling for Calculating Point Flattening and Point Dispersion Functions with MCNPX Code [1]

Results

Since one of the effective factors in neutron scattering distribution is the thickness of the sample tested, this contribution of scattering was investigated for a different thickness of sample with the same distance from the detector plate. For this purpose, water samples with thicknesses of 15 mm to 50 mm within 5 mm of the 100 * 100 (mm^2) detector plate were placed in front of the neutron beam and sample images were obtained with the neutron distribution data on the detector plate. Figure (3) shows the point distribution function of neutrons on the detector plate for different thicknesses, which is normalized to the relative intensity of neutrons

As can be seen, by decreasing the sample thickness, the scattering at the center of the object and at the edges increases substantially, requiring the correction function to reduce the scattering effects of neutrons in the sample. Other factors affecting the distribution of neutron scattering on the detector plane are the distance of the object to the detector. For this reason, a calculation has been made of the extent of this impact. Figure (4) shows the point distribution function of the neutrons on the detector plate for two thicknesses of 5 mm and 20 mm of water samples at different distances of 2 mm, 5 mm and 40 mm.

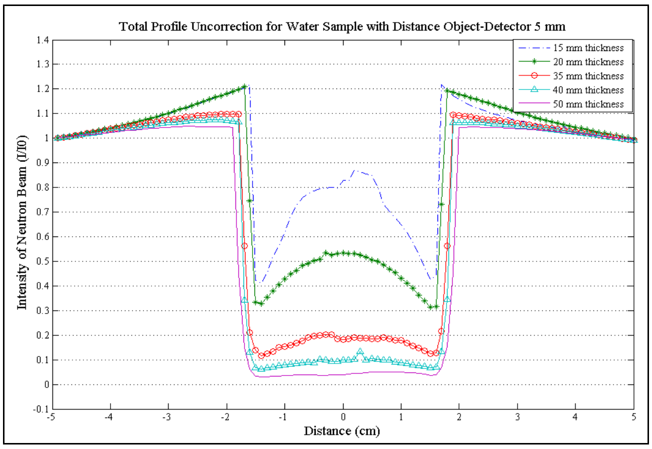


Fig 3: Distribution function of the neutron spot flattening on the detector plate for different water sample thicknesses

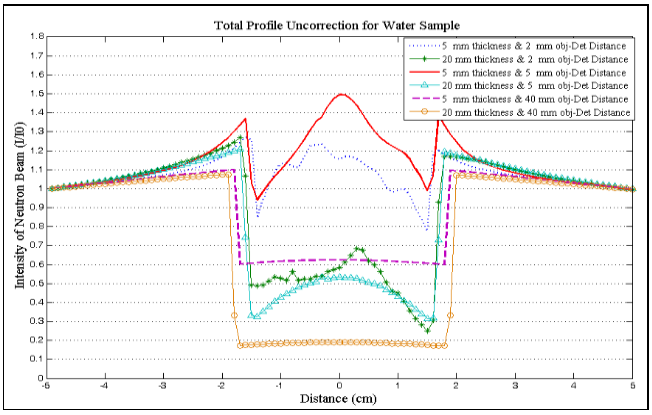
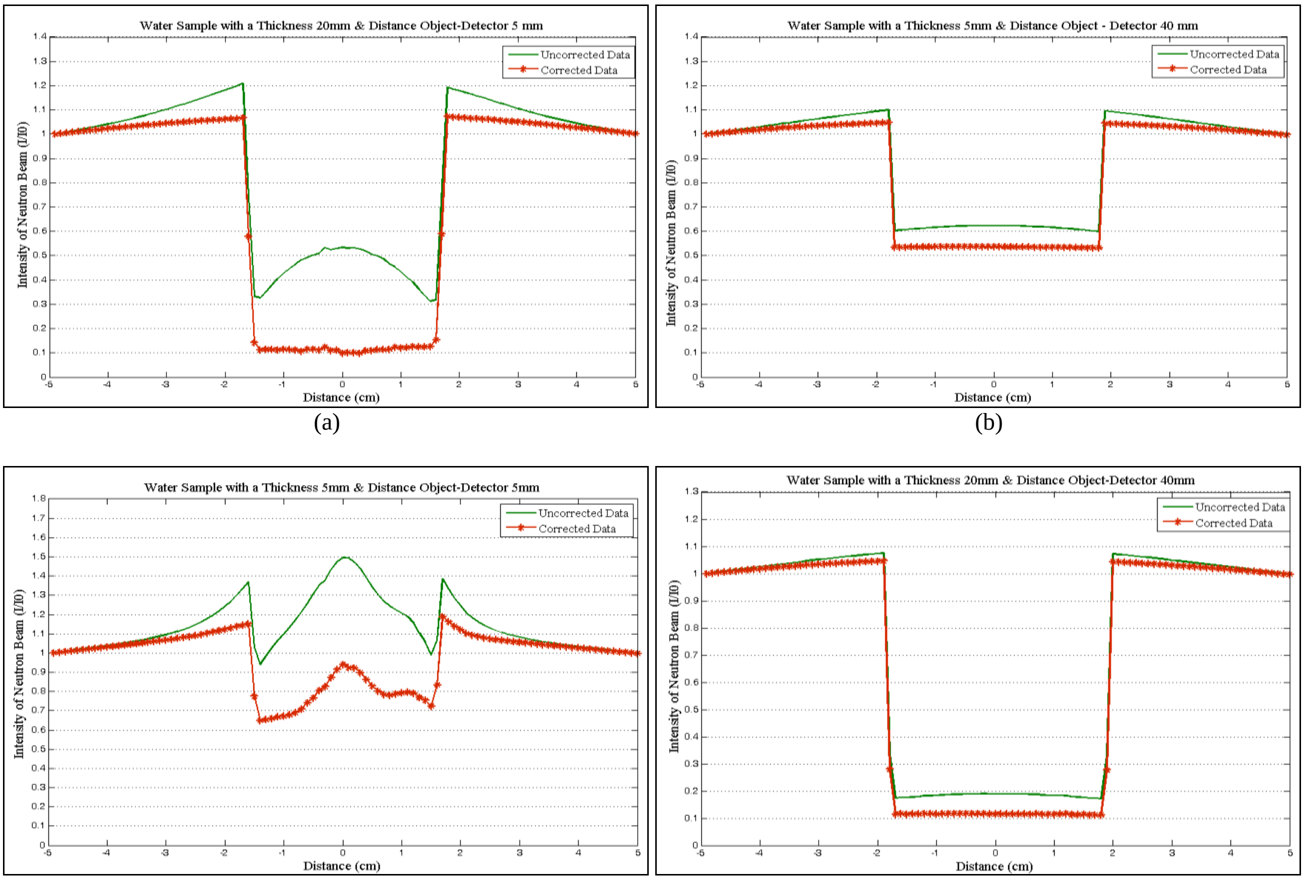


Fig 4: Distribution function of the neutron spot flattening on the detector plate for two thicknesses of 5 mm and 20 mm water samples at different distances of 2 mm, 5 mm and 40 mm

As can be seen, as the sample distance to the detector increases, the intensity of the neutrons reaching the detector decreases sharply, and in this case the scattering at the edges is increased so that the width of the object in the image is greater than the actual value displayed. (In these experiments the body width is cm3). However, for thicknesses less than 10 mm and close distances, the amount of neutron flexion due to impact and non-impact components will be greater than the unmodified component.

The correction algorithm was applied here is based on the subtraction of the point scattering function calculated for the entire sample area from the point scattering function caused by both the collision and non-collision neutrons. For example, in Figure (5), the distribution of neutron intensities on the detector plate is shown, before and before scatter correction for water samples with thicknesses of 5 mm and 20 mm at 5 mm and 40 mm distances from the detector.



(a) (b)

(b) (d)

Fig 5: neutron intensity distribution on the detector plate, before and before scatter correction for a sample of water a) 5 mm thick at 40 mm distance from detector b) 20 mm thick at 5 mm distance from detector c) 5 mm thick at 5 mm distance from the detector d) 20 mm thick at the distance from the detector

The image of the neutron distribution caused by the scattering component of the neutrons on the detector plate for the 35 mm thick water sample and 5 mm distance from the detector is shown in Figure 6.

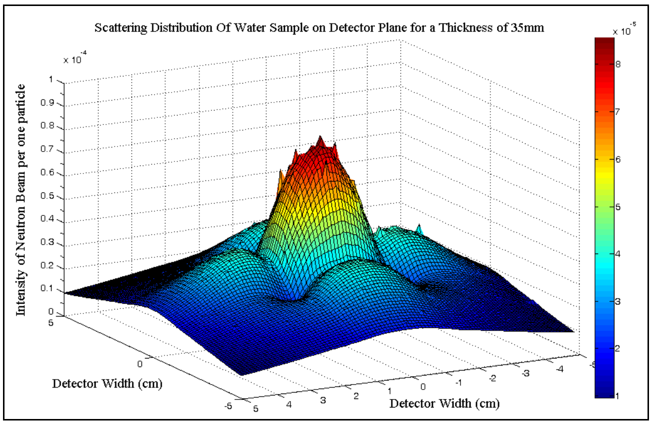


Fig 6: Image of the neutron distribution caused by the neutron scattering component on the detector plate for the 35 mm thick water sample and 5 mm distance from the detector

According to the correction algorithms applied to the neutron distribution functions, as can be seen, the scattering effects at the edges and at the center of the object are substantially eliminated in its radiographic images, making the edges appear sharp in the images.

Discussion

Neutron imaging is one of the most widely used methods for the qualitative and quantitative detection of materials, in particular hydrogenated materials and certain special elements (boron, lithium, etc.). In the two-dimensional neutron radiography system, many methods and algorithms have been proposed to correct the image, taking into account the factors involved in neutron scattering and subsequent distortions in the obtained images. In this study, the scatter correction method is applied based on an analytical function called point flattening function (PSF) in the discrete space of the neutron source and the detector plate.

For this purpose, the MCNPX Monte Carlo code, which has special capabilities for calculating the spatial distribution of neutrons on a detection plate, is used. Given that factors such as the type of sample material, its thickness, as well as the distance from the sample to the detector affect the distribution of the neutron scattering component and thus affect the quality and resolution of the images, a sample of water with thicknesses from 5 mm to 50 mm and from 2 to 40 mm from the detector plate, the neutron scattering correction algorithm was applied to the overall distribution of neutrons on the detector plate. ^{252}Cf was also used as a neutron source to produce a uniform and parallel beam. The results show that by applying the scattering function correction depending on the sample thickness and its distance from the detector, the sharpness of the images and their resolution significantly increase.

The present algorithm is capable of correcting the distortions caused by neutron scattering, in objects of different shapes and thicknesses, in experimentally obtained neutron radiographic images. This type of correction is particularly important for experimental setups where the object cannot be farther away than the detector (for example, where neutron parallelization is too weak or the detector front distance is too low).

References

1. Kardjilov N, Lehmann E, Vontobel P. ″Representation of the image formation in applied neutron radiography in terms of a PSF superposition ″Appl. Phys. A 74 [Suppl.], S228–S230 Applied Physics a Materials Science & Processing, ITMNR-4: Pennsylvania – SA, 2002.
2. Pleinert H, Koerner S, Lehmann E. ″Neutron signal transfer analysis” A, 1999, 424:177.
3. Brenizer JS. ″A review of significant advances in neutron imaging from conception to the present” Physics Procedia. 2013; 43:10-20.
4. Briesmeister, (Ed.) J.: ″MCNP – A General Monte Carlo N-Particle Transport Code, LA-12625-M. Version 4B Los Alamos National Lab. ″, Los Alamos, 1997.
5. Hassanein R, Lehmann EH, Vontobel P. "Methods of Scattering Corrections for quantitative Neutron Radiography ″, Nucl. Instr. & Meth, 2005, A542:353.
6. Lehmann EH, Vontobel P, Wiezel L. Properties of the Radiography Facility NEUTRA at SINQ and its Potential Use as European Reference Facility, 2007.
7. Durkee JW. "An MCNPX Accelerator Beam Source", LA-UR-09-03509, 2009.