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STUDY OF SCATTERING IN BI-DIMENSIONAL NEUTRON RADIOGRAPHIC IMAGES

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ABSTRACT

The effect of neutron scattering frequently causes distortions in neutron radiographic images and, thus, reduces the quality. In this project, a type of filter, comprised of cadmium (a neutron absorber), was used in the form of a grid to correct this effect. This device generated image data in the discrete shadow bands of the absorber, components relative to neutron scattering on the test object and surroundings. Scattering image data processing, together with the original neutron radiographic image, resulted in a corrected image with improved edge delineation and, thus, greater definition in the neutron radiographic image of the test object. The objective of this study is to propose a theoretical/experimental methodology that is capable of eliminating the components relative to neutron scattering in neutron radiographic images, coming from the material that composes the test object and the materials that compose the surrounding area.

1. INTRODUCTION

Neutron Radiography (NR) uses neutrons as test particles. Due to their peculiarities such as the absence of charge and matter interaction, very different from other types of radiation, neutrons present some advantages in the inspection of materials in Non-Destructive Tests (NTD).

NR is obtained by positioning the test specimen in a homogenous neutron beam; this beam is attenuated after passing through the thickness of the sample, and converted into ionized radiations (by specific converters) capable of sensitizing film or other detectors.

One important aspect to be considered in NR is its spatial resolution; therefore, studying the effect of scattering on the edges of the test specimen is a parameter of merit for the measurements, as it influences spatial resolution, for example, in terms of an object dimensioning. The interaction of neutrons with matter depends on the properties of the material composing the object and of the materials composing the surroundings. The effect of scattering reduces the quality of the neutron radiographic image, principally if the material is rich in hydrogen, given the high scattering cross-section of this element to thermal neutrons, making it necessary to eliminate this noise.

To correct the bi-dimensional neutron radiographic images, a cadmium grid is used (absorber of thermal neutrons) as a device capable of supplying the components relative to neutron scattering, through the image data of the discrete shadow bands of the absorber. Additional data can be obtained displacing that grid, and, also, those referring to minimum shadow will be used for interpolation, to estimate the bi-dimensional distribution of the scattering components relative to the object area and surrounding areas. Subtracting this data from those inherent to the original neutron radiograph image of the object, the corrected image is obtained, with better edge delineation and, therefore, a better definition of the dimensions of the object.

Therefore, the objective of this study is to propose a theoretical/experimental methodology capable of eliminating the components relative to neutron scattering in neutron radiographic images, coming from the material that composes the test object as well as those materials that compose the surrounding area.

2. METHODOLOGY

Figure 1 shows a model of the behavior of thermal neutrons through a block, where the transmitted neutron beam component [n_0] is detected by a converter; but the scattered neutrons [n_1] and other scatterings that occur on the surrounding [n_2] are also detected.

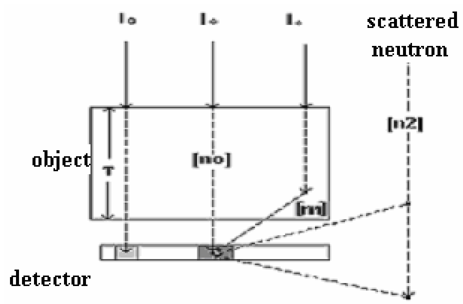
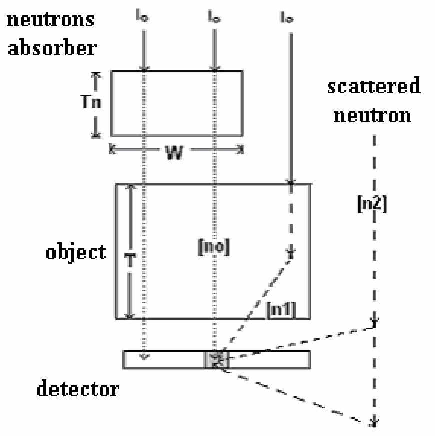
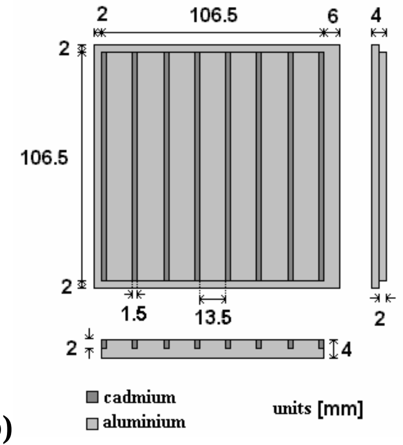


Figure 1 – Behavior of thermal neutrons through a plate of neutron scattering material.

To eliminate the effects of scattering, a grid of a material that absorbs thermal neutrons will be used, in other words, a material with high absorption cross-section (in our case cadmium) between the neutron source and the block, as can be seen in Figure 2.



(a)



(b)

Figure 2 - (a) Model of the behavior of thermal neutrons through a plate (test specimen) after passing through and absorber (b) Filter in the form of a cadmium grid.

The cadmium (Cd) absorber will absorb the thermal neutrons, making the component [n_0] negligible; however components [n_1] and [n_2] continue to sensitize the converter.

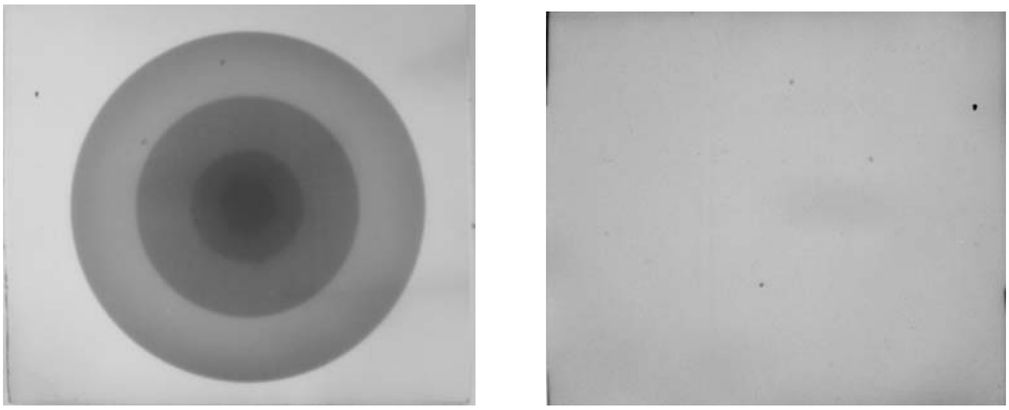
A first image of the sample is obtained, without the cadmium grid, a “pure” image of the test specimen. Then an image is obtained with the cadmium grid between the source and the test body, Figure 2. Next, two more images are taken adopting this same method, a small scanning of the test body through two displacements, from the original position of the cadmium grid, resulting in three images with the object and the cadmium grid, relative to the three positions of the cadmium grid. After capturing three different images with the cadmium grid, a synthesis of these images is realized. Synthesis consists of maintaining only the “image points” that refer to the shadows in the cadmium bands (scattered components in objects [n1] and [n2]) of the three positions into only one image. The synthesis image is now ready to pass through a process of linear interpolation to fill in all the image points that are needed to form a complete neutron radiographic image of the components of the neutrons scattered onto the component material of the test object and its surroundings. The methodology to obtain a neutron radiographic image of the scattered components is displayed on the diagram in Figure 3.

A second correction is done by correcting the effects of background radiation and follows the previously described steps of obtaining and processing images, where an estimated neutron image was created, the only difference is in the removal of the test object (acrylic disks).

3. RESULTS

The neutron radiographic images in Figures 1 and 2, as well as the other six images that refer to the displacement of the cadmium grid, with or without the test specimen, were obtained from the J-9 irradiation channel from the Argonauta reactor operating at 340 W for 30 minutes, captured with a Nikon Coolpix 995 digital camera.

The imaging shown in Figure 3 (a) was done without a cadmium grid, and was called the original test specimen image (OI). Figure 3 (b) displays the imaging done without the cadmium grid and without the object, which was called the black image (BI).

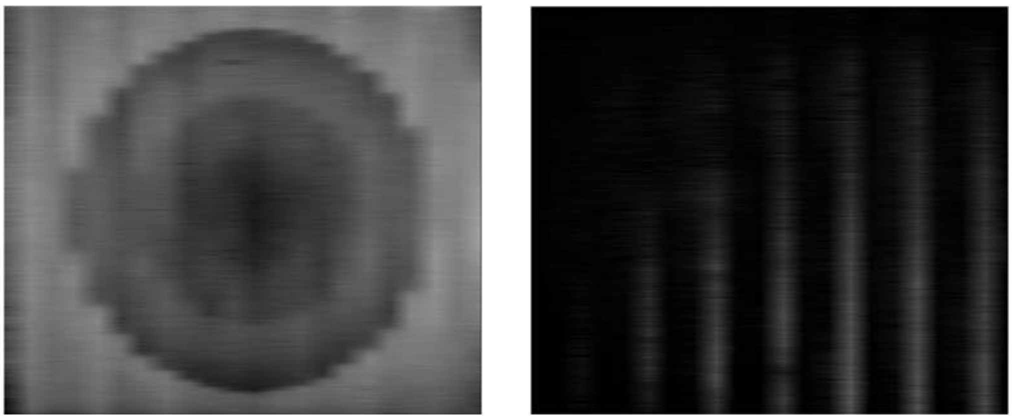


(a) - OI **(b) - BI**

Figure 3 – (a) NR Image in the original cadmium grid position with the test specimen (OI_0). (b) Black NR Image (BI).

After digitalization of the images, the matrixes were used by the TratImage Program, created to process, through image processing mathematical algorithms, the data of the digitalized images and generate data relative to the interpolated images with or without the test specimen, Figure 4 (a) and (b), as well as generate data relative to the corrected image Figure V. The data generated by TratImage (matrixes) are transformed into new images (a process inverse to digitalization) by the MatLab computer program.

Figure 4 (a) shows the interpolated Image that refers to the cadmium shadows in the three positions with the object (OII) and Figure 4 (b) shows the interpolated Image that refers to the cadmium shadows in the three positions without the object (BII).



(a) - OII **(b) - BII**

Figure 4 – (a) Image interpolated with the test specimen (OII). (b) Image interpolated without the test specimen (BII).

The Corrected Image (CI) a result of the treatment performed according to Equation 1, included in the TratImage program, the general objective of this study, is presented in Figure 5:

$$CI = OI - \left(\frac{OI - OII}{BI - BII} \right) \qquad (1)$$

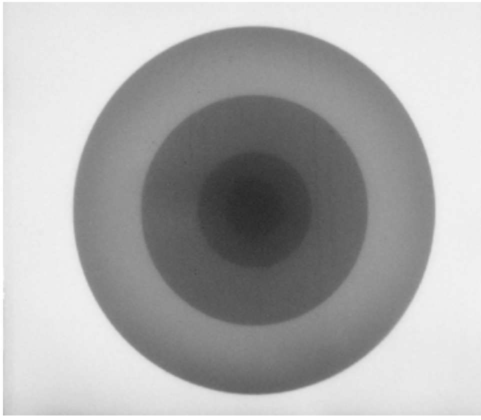
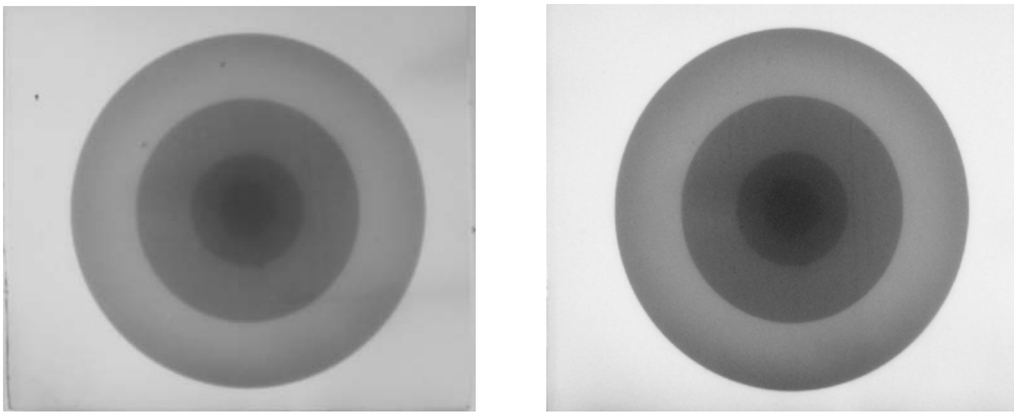


Figure 5 – Corrected Image (CI).

For purposes of comparison, images OI and CI are placed side-by-side, in Figures 6 (a) and 6(b), respectively.



(a) – OI **(b) - CI**

Figure 6 – Comparison of Original Image OI and Corrected Image CI. (a) Original Image of Object-OI. (b) Corrected Image-CI.

The following graph plots the grey level intensities of each pixel on the central lines of the OI and CI images, versus the abscise axis, where the scans are placed over the image central line, relative to the origin, represented by columns 1 to 1065.

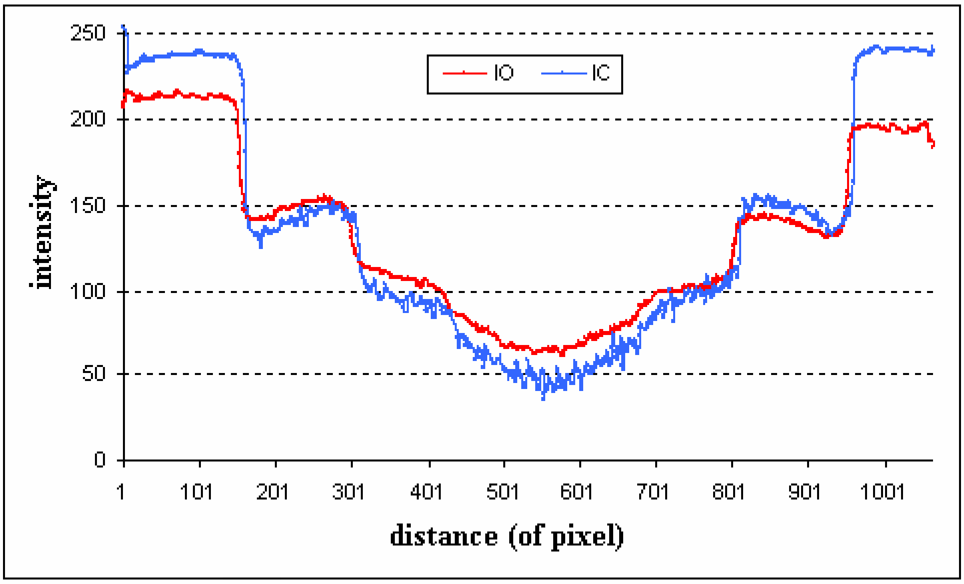


Figure 7 – Graph of the central lines of the Original (OI) and the Corrected (CI) Images.

4. CONCLUSIONS

As can be seen expressed by Equation 1, the use of the filter on the image represented in Figure 6 (a) results in an image, Figure 6 (b), with greater contrast and better delineated edges. In Figure 6 (b), in the CI image, the region relative to the area surrounding the test specimen has a grey level that is paler than that shown in Figure 6 (a), while in the areas that refer to PMMA disks, the grey levels are darker, resulting in better edge delineation, important for better dimensioning of the object. The homogeneity of the CI image relative to the OI image is another factor to be observed.

Analyzing the graph in Figure 7, degrees corresponding to the overlaid PMMA disks ("wedding cake") can be seen. The degrees seen in the curve in the CI image are larger and steeper than the corresponding ones in the OI image. The minimum and maximum absolute points of CI are further apart from one-another. Graphically, this means an increased contrast and an increased edge resolution, defined by the height of the degrees. The intensities of the grey levels, from the central column to the left of the image, observed in the OI image are smaller, which suggests a preferential scattering in this direction. On the other hand, this effect is almost imperceptible on the curve corresponding to the CI image, demonstrating that a correction occurred, improving the homogeneity of the image, being that the test specimen has no material discontinuities in the composing disks. In the CI image, greater grey intensities can be seen, and thus, expecting more noise. This is demonstrated in the intensity curves versus pixel by pixel scanning of this image, however, in the CI images, as shown in Figures 6 (A) and 6 (b), this is evidenced, as the noise is low, in relation to the intensity of the grey levels of the corrected image, which means that the ratio signal/noise increased.

After the transformation of the matrixes that refer to the Black Interpolated Images (BII), Object Interpolated Images (OII) and the Corrected Image (CI) performed with the MATLAB computer program, it was concluded that the use of a cadmium grid filter was efficient, extracting the components that refer to neutron scattering in the original neutron radiographic image. The good performance of the filter and the associated algorithm for correction was experimentally proved by the significant improvement in the original image of the object (OI), generating a corrected image (CI).

The set formed by the TratImage program, a scanning device, made of a cadmium grid and support, the methodology applied, was useful for the creation of a morphological filter, working in a spatial domain, capable to solve the specific problem of eliminating the neutron scattering components in neutron radiographic images.

Many methods for correcting images use computer programs, such as Image Pro-Plus, Adobe Photoshop, Corel Draw, among others and, although they are able to present good results, this correction method is specific for Neutron Radiographic images, and refer to correcting the effects of neutron scattering, becoming a filter to correct diffused edges.

Being that neutron radiographic images in real time generally have low resolution and poor clarity, the application of this morphological filter is also recommended.

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