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Development of a digital system for track - etch neutron radiography

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ABSTRACT

The use of track-etch foils for neutron radiography(NR) purposes is a well known technique [1,2,3,4,5,6,7]. The radiography is obtained by irradiating a sample in an uniform neutron beam and a boron based converter screen transforms the transmitted neutron intensity into 1.47MeV alpha-particles which are able to cause damages into the foil. During irradiation the foil and the converter are kept in a tight contact inside an aluminum cassette while the samples are positioned outside it. By means of a chemical etching the damages are enlarged and are called tracks and, they will form a two-dimensional image which is visible by naked eye. The evaluation of some radiographic parameters, which will characterize the image quality, are usually performed by employing conventional analog optical microphotometers. Because of several technical limitations of this methodology, the NR working group of IPEN-CNEN/SP has developed a digital system to perform such evaluation. The parameters obtained in both systems have been compared and have demonstrated a better performance of the digital system.

1. INTRODUCTION

The use of track-etch foils for neutron radiography(NR) purposes is a well known technique. The radiography is obtained by irradiating a sample in an uniform neutron beam and a boron based converter screen transforms the transmitted neutron intensity into 1.47MeV alpha-particles which are able to cause damages into the foil. During irradiation the foil and the converter are kept in a tight contact inside an aluminum cassette while the samples are positioned outside it. By means of a chemical etching the damages are enlarged and are called tracks and, they will form a two-dimensional image which is visible by naked eye [1]. The evaluation of some radiographic parameters, which will characterize the image quality, are usually performed by employing conventional analog optical microphotometers [2]. Because of several technical limitations of this methodology, the NR working group of IPEN-CNEN/SP has developed a digital system to perform such evaluation. The parameters obtained in both systems have been compared and have demonstrated a better performance of the digital system.

2. METHODOLOGY

The evaluation of the radiographic parameters demands the quantification of the light transmission through the radiography images. In the case of the digital system, the light intensity is evaluated in a gray level(GL) scale ranging from 0 to the darkest pixel to 255 to the brightest one. Among the studied parameters, the most important were:

2.1. Exposure interval(E): It is determined by means of the curves that relate Gray Level *vs* neutron exposure. A typical curve is shown in the Fig. 1 and, the best interval (shown by arrows) is that one for which the optical contrast, defined by (1), remains maximal [3].

$$G = d(GL)/d(\log E) \qquad (1)$$

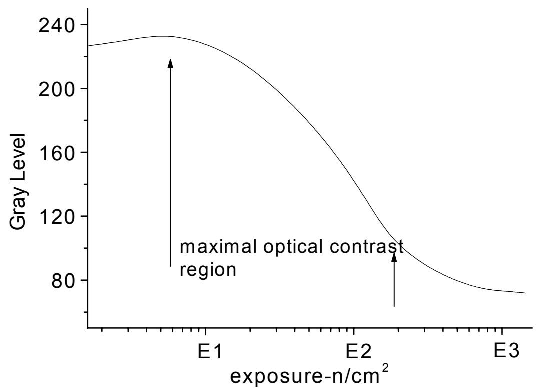

Fig 1. Typical curve showing the Gray Level behavior as functions of the neutron exposure.

2.2. Spatial resolution(U): In radiography, the spatial resolution is defined as the minimum distance that two objects must be separated before they can be distinguished from each other [4]. The resolution is usually quoted in terms of the total unsharpness(U_t) and results from the combined effect of the intrinsic unsharpness(U_i) from the foil/converter screen combination and of the geometric unsharpness(U_g) from the angular divergence of the neutron beam. It is usually obtained by scanning the light transmission distribution at the interface between the images of a neutron opaque object(gadolinium foil-100μm). and the one corresponding to the direct neutron beam. An Edge Spread Function-ESF(2) is fitted to the resulting distribution and the total unsharpness is given by(3) [5].

$$GL = p_1+p_2(\arctan(p_3.(X-p_4))) \qquad (2)$$

$$U_t=2/(p_3) \qquad (3)$$

where X is the scanning coordinate and p_1, p_2, p_3 and p_4, are free parameters.
A typical scanning is shown in the Fig.2.

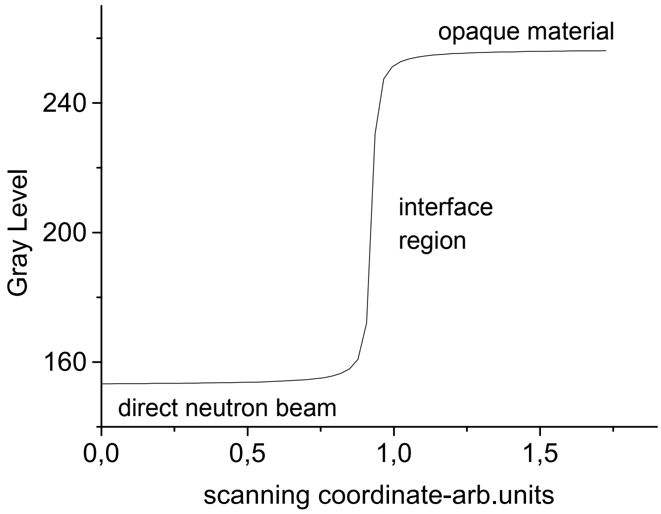

Fig 2. Typical light transmission distribution at the interface region.

2.3. Capability to discern thickness of materials(Δx):
In order to evaluate this parameter, the sample was an iron step wedge with thickness varying from 2 mm to 12 mm. It was determined by fitting, in the data of Gray level(GL) *vs* sample thickness(x)(see typical example in Fig.3), a linear function given by (4) [6].

$$GL(x) = GLo + C.x \qquad (4)$$

where:
GLo is the Gray Level intensity for the direct neutron beam and C is its slope.

The capability to discernible thickness, is given by the derivative of (4) as

$$\Delta x = \Delta(GL)/C \qquad (5)$$

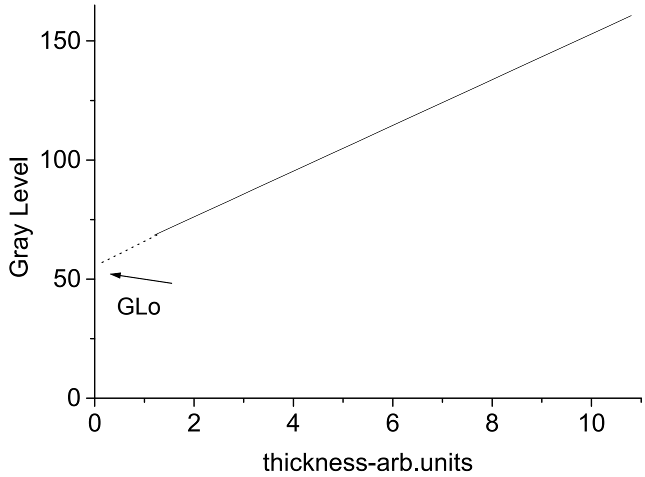

Fig 3. Behavior of the Gray Level as functions of the sample thickness.

3. EXPERIMENTAL

In the present work the irradiations and the radiographs were obtained at the neutron radiography facility installed at the IEA-R1 Nuclear Research Reactor. The track-etch foil CR-39 (500μm thick) has been employed to record the images [7]. The chemical etching was performed during 25 minutes in a KOH (30%) aqueous solution at a constant temperature of 70^{o}C [2]. The digital system shown in Fig 4. is a photo enlarger in which a parallel light beam perpendicularly impinges the foil. The transmitted intensity is projected in a white screen and an analog video camera captures this image and a capture frame grabber, installed in a standard computer, converts it in a 8 bit the digital form.

Fig 4. Digital system for light transmission analysis.

4. DATA ANALYSIS

Table 1 shows a comparison between the values of the radiography parameters obtained by using the microphotometer and the proposed digital system.

Table 1. Radiography parameters

	Microphotometer	Digital
Exposure interval(n/cm^2)	$2x10^9<E<2x10^{10}$	$6x10^7<E<4x10^9$
Discern capability for iron(micra)	~380	~130
Spatial resolution(micra)	20	150

Although these results are still under analysis, we can underline that the proposed digital system provides:
- a greater exposure ratio ~67 while the microphotometer it is only 10. This means that the contrast remains maximal for greater exposure intervals
- a higher capability to discern thickness changes
- a worse spatial resolution in the image. This result is limited by several factors such as the screen graininess, camera's CCD and frame grabber.

As additional features it is important to mention that the cost to acquire and to keep the digital system operational are smaller than the microphotometer, the time interval spent to perform the measurements are about 100 times smaller and, since the measurements are automatic no visual tiredness is necessary.

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