Accurate Measurement Technique of Water Thickness in Al block by using Grid Method

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1. Introduction

The quantitative neutron imaging technique requires an exact relation between the measured neutron attenuation and the real macroscopic attenuation coefficient for every point of the sample. In this way quantitative information about the material composition or the sample thickness can be obtained. The assumption used in these cases that attenuation of the neutron beam through the sample is exponential:

$$\Phi = \Phi_o e^{-\sum_i \mu_i t_i} \quad (1)$$

Where Φ is the attenuated neutron flux, Φ_0 is incident neutron flux, μ is attenuation coefficient, t is thickness of material. Equation (1) is valid only in an ideal case, where a monochromatic beam, non-scattering sample and non-background contribution are assumed. In the real case these conditions are not fulfilled and in dependence on the sample material we have more or less deviation from the exponential attenuation law. Because of the high scattering cross-sections of hydrogen for thermal neutrons, the problem with the scattered neutrons at quantitative investigations of hydrogenous materials (as PE, PMMA, oil, H2O, etc.) is not trivial. For these strong scattering materials the neutron beam attenuation is no longer exponential and the there is deviation between calculated and real thickness [1,2,3]. At present research shows that how much water thickness is distorted by scattering effect and how much the scattering effect is reduced by grid method.

2. Experimental Set-up

Measurement of the thickness of a water step was carried out to show the efficiency of the present method. Figure 1 shows the device constructed to allow many thicknesses of water to be placed in the beam. It consists of 20 steps of a machining into an aluminum plate with each step 0.1 mm thicker than the previous step. There are water reservoirs at side of water step in order to supply water into water step well. However, since water has high scattering cross-section for thermal neutron, the water reservoir might be high neutron scattering source. The boron plate with 1 cm thickness was installed between reservoir of Al block and beam exit to remove the neutron scattering effect. Figure 2 shows the schematic diagram of grid. The rod of the grid was made from B_4C fine powder less than 5 μm filled in thirty rectangular ducts 3 mm × 3 mm machined in an aluminum plate 5 mm in thickness. The grid was installed between Al block and the scintillator.

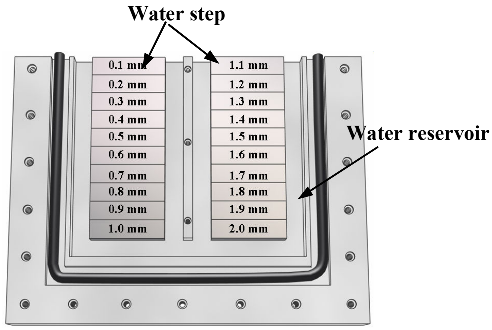

Figure 1. Schematic Diagram of Al Block

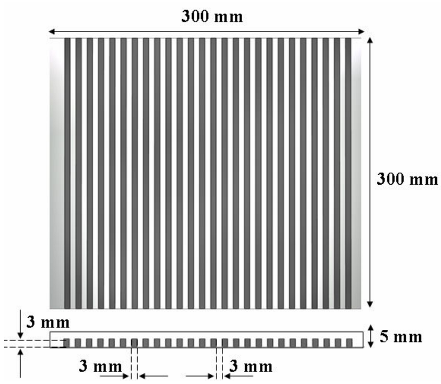

Figure 2. Schematic Diagram of Grid

A cooled-CCD camera system at the HANARO in KAERI was used for the measurement. The distance between the converter and the Al block was fixed 25 mm. The exposure time was 1 seconds. Three series of measurement of the water step thickness with and without boron plate and the grid were carried out.

Two kinds of image were taken to calculate the water step thickness using neutron imaging technique, with and without water. The thickness calculation process is like as:

(1) Capture images of Al block without water (***dry***)
(2) Capture images of Al block with water (***wet***)
(3) Divide the ***wet*** image by ***dry*** image and take the negative natural log to get the value of μt.

$$T = -\ln(\frac{\Phi_{wet}}{\Phi_{Dry}}) = -\ln(\frac{\Phi_o e^{-(\sum_i \mu_i t_i + \mu_{water} t_{water})}}{\Phi_o e^{-\sum_i \mu_i t_i}}) \qquad (2)$$

(4) Finally the water thickness can be calculated if the linear attenuation coefficient of water is known.

$$t_{water} = \frac{T}{\mu_{water}} \qquad (3)$$

At present study, the linear attenuation coefficient was used 0.345 mm^{-1} based on literature [4].

3. Results and Discussion

Calculated values of water step thickness by described process are shown at from Figure 3 to Figure 5 according to the test conditions. It can be seen from the data that the calculated thickness without boron plate and grid is distorted due to scattering effect as shown at Figure 3. Although neutron scattering effect by water reservoir was removed by boron plate, the values are still distorted and lower than actual thickness as shown Figure 4. It means the water with small thickness makes neutron scattering too. When the boron plate and the grid were used, the every scattering effect by water reservoir and water step was removed as shown Figure 5. In spite of small thickness of water, it makes a scattering effect and the calculated thickness will be lower.

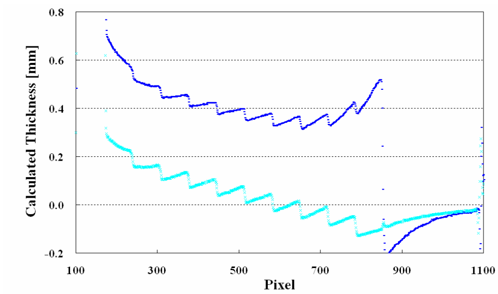

Figure 3. Test result without boron plate and grid

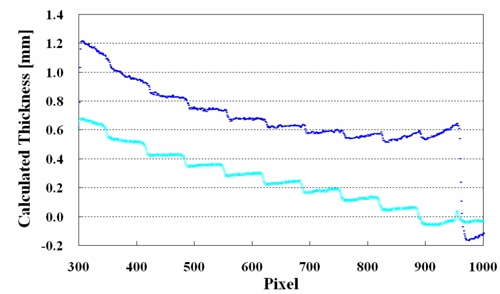

Figure 4. Test result with boron plate

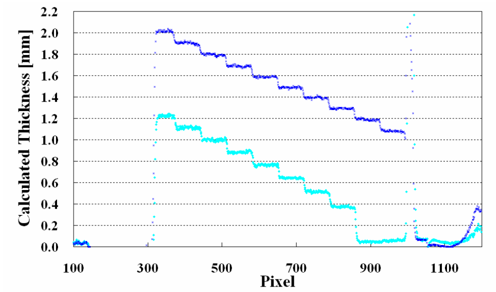

Figure 5. Test result with boron plate and grid

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4. Conclusion

Water thickness was accurate measured by using neutron imaging technique with grid. Since water has high scattering cross-section, calculated thickness is distorted even though small thickness. Therefore the grid must be needed to quantify thickness with high scattering materials, like as water, and hydrogen.

ACKNOWLEDGEMENTS

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REFERENCES

[1] N. Kardjilov, E. Lehmann, P. Vontobel, Appl. Phys. A 74 (Suppl.),S228, 2002

[2] N. Kardjilov, F. de Beer, M. Middleton, E. Lehmann, B.Schillinger, P. Vontobel, Corrections for scattered neutrons in quantitative neutron radiography, Proceedings of the Seventh World Conference on Neutron Radiography, 2002.

[3] J. Briesmeister (Ed.), MCNP—a General Monte Carlo NParticle Transport Code, Version 4B, Los Alamos National Lab., Los Alamos, 1996.

[4] J.C. Domannus, G. Bayon, L. Greim, A.A. Harms, H.P. Leeflang, J.F.W. Harkgraf, R. Matfield, and D.J. Taylor, Practical Neutron Radiography, London, Kluwer Academic Publishers, 1992.