Accurate Measurement Technique of Water Thickness in Al block by Neutron Flux Correction

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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:

$$I = I_o \exp(-\sum_i \mu_i t_i) \quad (1)$$

Where I is the attenuated neutron flux, I_o 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 [1,2,3]. Since two kinds of images (called ***dry*** and ***wet***) are required to quantity from neuron image, additional important assumption is that neutron flux isn't varied with time. If the test span between ***dry*** and ***wet*** images isn't long, for example a few seconds, the neutron flux variation wouldn't be important. However, at the case of fuel cell research, the time span between dry and wet images is from several hours to several days. Therefore the neutron flux variation must be corrected in order to quantify accurately from the neutron images. At present study, we show that how much neutrons are varied at Neutron Radiography Facility (NRF), HANARO and how to solve that problem. But at this study we don't consider the neutron scattering effect which is caused by high scattering cross-section material, especially water.

2. Experimental Set-up

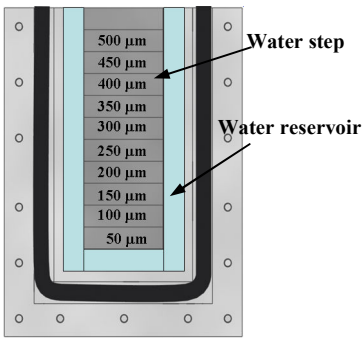

Figure 1. Schematic Diagram of Al Block

Figure 1 is the device constructed to allow many thicknesses of water from 50 μm to 500 μm to be placed in the beam. It consists of 10 steps of a machining into an aluminum plate with each step 50 μm thicker than the previous step. There are water reservoirs at side of water step in order to supply water into water step well.

3. Neutron Imaging Process

A cooled-CCD camera system and NRF at the HANARO in KAERI were used for the measurement. The distance between sincillator and Al block was varied from 25 (the shortest distance) to 85 (the ration of distance and width of Al block is 1:1) mm. The exposure time was 1 and 2 seconds.

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

(1) Capture images of Al block without water (***dry***)

$$I_{dry} = I_{o\_dry} \exp(-\sum_i \mu_i t_i) \quad (2)$$

(2) Capture images of Al block with water (***wet***)

$$I_{wet} = I_{o\_wet} \exp(-(\sum_i \mu_i t_i + \mu_{water} t_{water})) \quad (3)$$

(3) Divide the ***wet*** image by ***dry*** image and take the negative natural log to get the value of μt .

$$T = -\ln\left(\frac{I_{wet}}{I_{Dry}}\right) = -\ln\left(\frac{I_{o,wet} \exp(-(\sum_i \mu_i t_i + \mu_{water} t_{water}))}{I_{o,dry} \exp(-\sum_i \mu_i t_i)}\right)$$

$$= -\ln\left(\frac{\Phi_{o,wet}}{\Phi_{o,dry}}\right) + \mu_{water} t_{water} \quad (4)$$

(4) Finally the water thickness can be calculated if the offset by neutron flux variation is known.

$$t_{water}\mu_{water} = T + \ln\left(\frac{I_{o,wet}}{I_{o,dry}}\right) \quad (5)$$

Although neutron flux at specific position is changed with time, its relative ratio between ***dry*** and ***wet*** images is constant. If the reference position at outside of specimen is selected and has been monitoring during test time, the offset due to neutron flux variation can be removed by using relative ratio of reference position. At present study,

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

4. Results and Discussion

Prior to calculate the water thickness by using Al block and neutron imaging technique, the neutron flux variation at NRF, HANARO was measured with 3 exposure time for about 2 hour as shown in Figure 2. The neutron flux of NRF is varied about 3 percent at specific position. If the neutron flux isn't varied with time, the calculated water thickness must be same under different exposure time. But the result without neutron flux correction shows that there is deviation according to the exposure time as shown Figure 3. Even though the test span between ***dry*** and ***wet*** images isn't long, about 10 min, the calculated water thickness is different according to the exposure time.

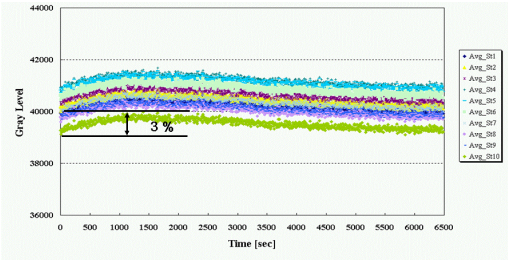

Figure 2. Neutron flux variation at NRF with time

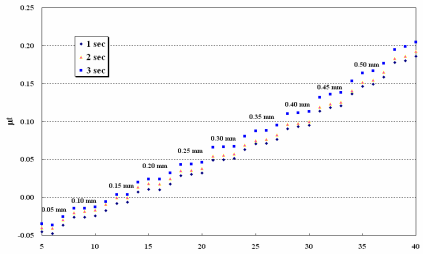

Figure 3. Test result without neutron flux correction

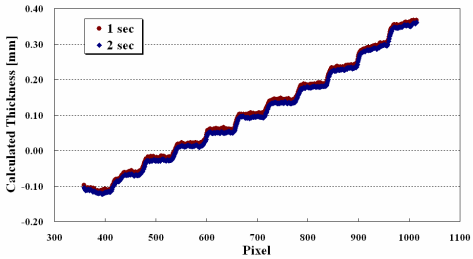

Figure 4. Test result with neutron flux correction at 25 mm

Therefore the neutron flux must be corrected. Figure 4 shows calculated water thickness by using the neutron flux correction described section 3. In this case, there is no variation under exposure time. But the calculation is under-estimated compared with real water thickness. It comes from neutron scattering effect because water has high scattering cross-section. Usually the neutron scattering effect can be removed with longer distance between test specimen (here is Al block) and scintillator. When the distance was changed from 25 to 85 mm, the calculated water step thickness is well matched with real value as shown in Figure 5. However, spatial resolution of neutron imaging technique is affected the distance between specimen and scintillator. Longer distance, it means, poorer spatial resolution.

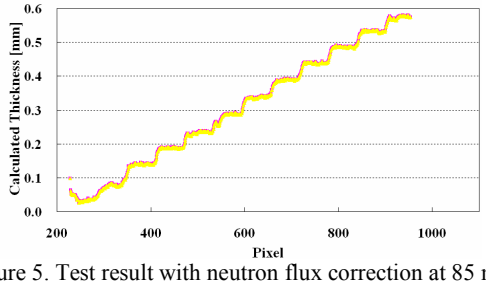

Figure 5. Test result with neutron flux correction at 85 mm

5. Conclusion

Water thickness was accurate measured by using neutron imaging technique with neutron flux correction. Since neutron imaging technique needs two kinds of images, dry and wet, to quantity, the neutron flux variation must be considered to obtain accurate water thickness. Although the quantitative data can be obtained by considering neutron flux correction, there is another distortion due to neutron scattering effect at high scattering cross-section material, for example water and hydrogen. Therefore it must consider neutron flux variation and scattering effect when the test specimen has high scattering cross-section.

ACKNOWLEDGEMENTS

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