ESTIMATING NEUTRON SCATTERING EFFECT AT DIFFERENT SAMPLE TO DETECTOR DISTANCE WITH WATER THICKNESS CALIBRATION

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Summary: The effect of neutron scattering and beam hardening becomes more serious with increase of water content and decrease of the sample to detector distance during the neutron radiography test. If the sample was fixed far away from some key positions, the effects of neutron scattering and beam hardening can be offset a lot. Current investigation is to find the suitable sample position using neutron radiography facility at the cold neutron guide B of CARR. The calibration equation was also developed to correct these effects when the water thickness is lower than 10 mm.

1. INTRODUCTION

The estimation and correction of the effects of neutron scattering and beam hardening were very important to accurately measure water content in porous media using neutron radiography [1, 2]. Especially with the increase of water content in porous media, the neutron scattering is much more problematic because the relationship between neutron transmission and water thickness will deviate from classical *Lambert-Beer* law. The scattered neutrons can reach the detector and result in the increase of the transmission causing underestimation of water content in the sample. Beam hardening occurs in case the neutron beam is polychromatic and low energy neutrons are more attenuated than high energy neutrons [2]. Two methods have been developed to correct neutron scattering and beam hardening effects. One is to use the point scattered functions based on Monte Carlo simulations as reported by Hassanein et al [3, 4]. Based on this method, energy spectrum, detector type, distance between sample and detector of a special neutron facility should be considered. The other approach is to develop an empirical water thickness calibration equation for a specific instrumentation configuration [2, 5]. Correction of the underestimation of water content caused by neutron scattering and beam hardening can be achieved by measure the transmission of water in calibration cells. The thicknesses of water in calibration cell are known. Moreover, the degree of these effects is more serious when the sample is positioned closed to the detector. The non-linearity relationship between neutron transmission and water thickness increases as the decrease of the distance between sample and detector. Contrarily, the geometric unsharpness decreases as the distance between sample and detector increasing [2]. Thus, to get a balance between neutron scattering and geometric unsharpness, the estimation of neutron scattering and beam hardening effect at different distance between sample and detector is important for the application of neutron radiography to investigate water content in porous media [6]. Here, water calibration measurement was performed to obtain water attenuation coefficients and corresponding correction parameters for the neutron imaging facility at the cold neutron guide B of China Advanced Research Reactor (CARR) for the first time.

2. EXPERIMENTAL METHOD

A special aluminum water calibration cell with a cross-section of 2.5 cm×10 cm space, with a 0.5 mm thickness step increment every 5 mm was prepared. The water calibration cell was imaged using neutron radiography

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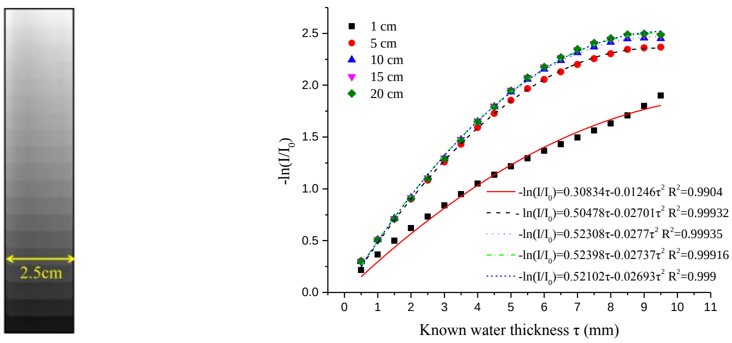
facility at the cold neutron guide B located at guide hall of CARR in the China Institute of Atomic Energy (CIAE). More details about the used facility can be found in these references [7, 8]. The exposure time for each radiography image was 40 seconds. The experimental protocol includes: (1) obtain the flat field images and dark current images; (2) obtain the neutron radiography of water calibration cell without water at 1, 5, 10, 15 and 20 cm far away from the detector; (3) obtain the neutron radiography of water calibration cell filled with water at the same position with step (2); (4) process the acquired neutron radiography images including image normalization, median filter, logarithm operation etc as reported by Kang et al. [2]. After these operations, $-\ln(I/I_0)$ values can be extracted on the images. I_0 and I are the incident and transmitted beam intensity, respectively

3. RESULTS

The relationship between the transmission and water thickness is not linear and this non-linearity rises as the increase of water content and the decrease of distance between sample and detector as shown in Figure 1 (b). The degree of neutron scattering and beam hardening effect is most serious when the sample was positioned 1 cm far away from the detector. It was also found that the effect of neutron scattering reduced a lot as the sample was positioned more than 5 cm away from the detector. Moreover, the calibration equation of water thickness with various correction parameters was developed to fit the obtained data. It indicates that the effect of neutron scattering and beam hardening can be corrected with different correction parameters at different distance between sample and detector (1 cm – 20 cm) as the water thickness was less than 10 mm.



(a) (b)

Figure 1: Result of water transmission image for the wet area of the calibration cell after logarithm and further negative operation and corresponding $-\ln(I/I_0)$ values extracted from this type image. (a) Image of wet area of the calibration cell at 1cm far away from the detector. (b) Plot and fitting of $-\ln(I/I_0)$ values versus known water thickness τ (mm) for the water calibration cell at five different position ie. 1, 5, 10, 15, 20 cm from the detector at CARR neutron imaging facility. The value of $-\ln(I/I_0)$ presented in figure (b) was the mean value on the central area of each step in figure (a).

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