THE APPLICATION OF NEUTRON RADIOGRAPHY TO DETERMINE THE SORPTIVITY OF SANDSTONES

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Summary: Neutron radiography was used to monitor wetting front and water volume during water imbibition in sandstone as well as the time-lapse water content maps. After correction of neutron scattering and beam hardening effect, the cumulative water volume measured by neutron radiography shows good agreements with those measured by weighting methods. The sorptivities were calculated based on the wetting front and cumulative water volume data.

1. INTRODUCTION

The water flow feature in partially-saturated sandstones has caused much concern in the field of petroleum engineering [1], CO_2 geological sequestration and the maintenance of buildings [2]. Recently, non-destructive examination methods including X-ray imaging [3], nuclear magnetic resonance [4] and neutron imaging [5] have been widely used to monitor water transport in porous media. Compared with X-ray imaging, neutron imaging has unique advantages in identifying the light elements rich materials such as water, oil and etc in abiotic non-hydrogenous porous media because neutrons can be attenuated strongly due to the presence of hydrogen in the materials [5]. Through normalization, neutron imaging can be used to present net water distribution in porous media in two dimensions (neutron radiography) [6] and three dimensions (neutron tomography) [7]. It is also confirmed that the unsaturated flow theories which well established in soil physics is very useful to describe water flow in unsaturated porous stones with parameters obtained by non-destructive examination methods. Thus, we used neutron imaging facility at China Advanced Research Reactor (CARR) to investigate water imbibition in two kinds of sandstones with different microstructures. After the correction of neutron scattering and beam hardening by calibration, the wetting front and the cumulative water volume absorbed by the sandstones with the elapse of imbibition time were extracted from neutron radiography images. The validity of neutron radiography was confirmed by traditional weight methods. Then, the sorptivities calculated based on the wetting front and cumulative water volume data were compared. The time-elapse water content maps based on neutron radiography in the sandstone samples were presented at last.

2. EXPERIMENTAL METHOD

The neutron radiography experiments were performed at the cold neutron guide B located at guide hall of CARR in the China Institute of Atomic Energy (CIAE). The neutron flux rate was 1.03×10^7 n/cm^2/s when the reactor operated at 20 MW power. The facility provides most neutrons between wavelengths of 0.8 and 10 Å (with a peak at 2.9 Å). The detector was equipped with a 100 μm thick Li6F/ZnS (Ag) scintillator and a DW936 Ikon_L ANDOR CCD camera system, giving a spatial imaging resolution of 130 μm [8]. The exposure time for each radiography image was 10 seconds. The experimental protocol includes: (1) obtain the flat field images and dark current images; (2) fix the dry sandstone sample above an elevatable aluminum water container at 1cm far away from the detector and obtain the neutron radiography of the dry sandstone sample which were called dry images

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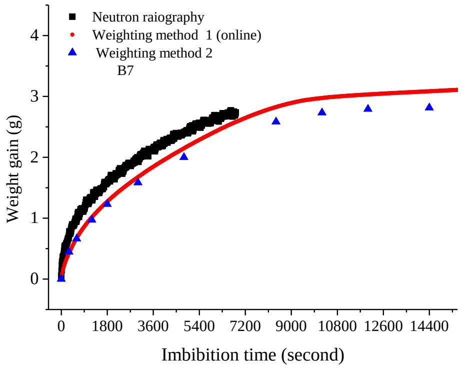
here; (3) keep neutron radiography acquisition mode and gradually raise the water container until the bottom end of the sample (approximately 5 mm) is immerged in the water to obtain the wet images.

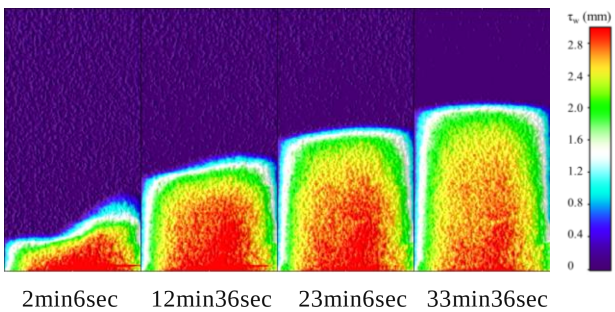
The acquired neutron radiography images were processed as follows: (1) all the dry images and wet images were normalized with respect to the flat field images and dark current images and then despeckled using a median filter (3 pixels ×3 pixels) to remove bright pixels mainly due to scattered γ-rays; (2) all the normalized wet images were divided by the normalized dry images to remove the contribution of dry sandstone sample and the net water transmission images were obtained until this step; (3) all the net water transmission images was divided by the rescale factor to correct the neutron beam fluctuations; (4) further mathematically operation was performed on all the above images based on a calibration equation to get images on which the value represent real water thickness (τ_w, mm) along the neutron beam direction; (5) on the profile along the direction of water imbibition, the position on which the value decrease to zero was identified as the wetting front and all the values on the region of interest were added together to get the cumulative water volume.

3. RESULTS

Neutron radiography can effectively identify the wetting front which increased linearly with the square root of imbibition time. The reason for the deviation at some points between the results of traditional weighting method and neutron radiography can be attributed to the interruption of water supply when the tradition weighting method was used and the calibration equation may not be perfect to correct the effect of neutron scattering (see Figure1 (a)). The linear relationship was also verified between the cumulative absorbed water mass and the square root of imbibition time by both the weighting method and the neutron radiography method. The sorptivity value calculated based on the cumulative water volume is 5.2 times as much as that calculated by wetting front data. The difference is in expectation because the area of the sample bottom is about 4.9 cm^2. The water content maps revealed by neutron radiography were shown in Figure 1(b).



(a)



(b)

Figure 1: Results of the application of neutron radiography and traditional weighting method during water imbibition in sandstone B7. (a) Comparison of weight gain (g) versus imbibition time (second) during water imbibition. (b) Several selected time-lapse water content maps revealed by neutron radiography.

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