Contribution ID : **99** Type : **Oral**

Neutron radiography of water imbibition in a smooth-walled fracture within sandstone

Tuesday, 4 September 2018 09:20 (20)

Water spontaneous imbibition in unsaturated fractured rocks is a ubiquitous phenomenon in nature and engineering such as the enhanced oil recovery by water flooding, the storage of hazardous wastes underground and the development of geothermal et al. In the presented work, direct visualization of water imbibition in a vertical smooth-walled fracture with a width of ~114 μm within a low permeability silty sandstone sample was achieved using neutron radiography at China Advanced Research Reactor (CRAA). The high-speed imaging mode i.e. 10 frames/second was employed to capture the rapid transport of water in the fracture at first 100 seconds of imbibition. Then the neutron image was captured every 2 seconds to improve the image quantity until the sample was saturated by water. Based on the neutron images, the wetting front was tracked on both vertical and horizontal directions to calculate the sorptivity. It was found six stages can be distinguished based on the varieties of sorptivity determined along the vertical smooth-walled fracture. The wetting front can travel at the height of ~17 mm along the smooth-walled fracture during the first 0.5 seconds of imbibition. Then the advance of wetting front along the vertical smooth-walled fracture slowed down due to the effect of gravity and water transport from fracture to matrix. Once the lower half of the sample was saturated by water, the infiltration of the wetting front along the vertical smooth-walled fracture accelerated again. The sorptivity determined along the horizontal direction varied in the range of 0.3073~0.3663 mm/s-0.5. Moreover, cumulative absorbed water volume in the investigated sandstone sample was determined at different imbibition time after the correction of neutron scattering and beam hardening effect. It was found the cumulative absorbed water volume increased linearly with the square root of time at two stages. Cumulative absorbed water volume in the sample grew much fast at the first 4 seconds of imbibition. At last, the time-lapse water content map of water imbibition in the investigated silty sandstone sample was presented. It seems the first report about of the visualization of the full process of water imbibition in the smooth-walled fracture within a low permeability silty sandstone sample by neutron radiography.

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Session Classification : Speaker Sessions and Seminars

Track Classification : Geoscience