Characterization of porosity inside limestone as a reservoir of oil using neutron tomography

Characterization of porosity inside limestone as a reservoir of oil using neutron tomography

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Abstract. As it is well known, limestone is a type of sedimentary rock that has a function as a reservoir of oil and gas. One of the factors that affect fluid saturation of the reservoir is the distribution of porosity inside the limestone that represents a percentage of the total available space for the oil and gas to fill in. Since hydrogen and carbon have strong attenuation to the thermal neutron, the oil-filled in the porosity can be investigated by the neutron tomography technique. Therefore, neutron tomography can be used to visualize the distribution of the porosity of the limestone. In this work, we report the characterization of the porosity inside the limestone obtained from the oil and petroleum gas institution of Indonesia using the neutron tomography technique. Characterization of the porosity using X-ray tomography technique also has been done in order to compare the results. The results show the neutron tomography technique is useful to visualize and characterize the porosity inside the limestone.

1. Introduction

National Nuclear Energy Agency of Indonesia (BATAN) has some instruments that are dedicated to the characterization of materials in many fields. One of the instruments that are useful as a tool for non-destructive examination is a neutron radiography facility installed at Multi-Purpose Reactor of G. A. Siwabessy at the Serpong Nuclear Area. The BATAN's neutron radiography facility has been upgraded for tomographic data acquisition, and has been utilized for characterization and non-destructive examination of industrial materials as well as in the fields of agriculture, medicine, and archaeology [1-3]. In the field of geology and building construction, utilization of the neutron radiography has been reported as well. The neutron radiography has been used to characterize porosity inside the materials such as concrete of cultural heritages building,etc [4-11].

Indonesia has a lot of mineral resources where oil and gas are the mainstay mineral resources. Limestone is one of the most versatile minerals used in the oil and gas industry. As a reservoir of the oil and gas, the limestone has a porosity that indicates available space for the oil and gas to fill in. Since the oil consists of hydrocarbon and the hydrogen and carbon have strong attenuation to the thermal neutron, the oil-filled in the porosity can be investigated by the neutron tomography technique. Therefore, neutron tomography can be used to visualize the distribution of the porosity of the limestone.

This paper will describe the capability of the neutron radiography facility to characterize the porosity inside limestone using the neutron tomography technique.

2. Methods

The sample of the limestone that is new and obtained from the oil and gas institution of Indonesia, is in cylindrical form with 35mm in diameter and 50mm in length. The experiments of the same sample were carried out at the neutron radiography of BATAN and X-ray Radiography facility of PSI Switzerland as well. Figure 1 shows the photograph of the sample of the limestone. The sample is put on the rotation table that can be rotated with the minimum step of 0.1^{o}.

Figure 1. Photograph of the limestone

The neutron radiography/tomography at Multi-Purpose Reactor of G. A. Siwabessy has a 30 cm diameter of outer collimator (beam size), 10^6 to 10^7 n/cm^2 sec of neutron flux at sample position, 83 of collimation L/D ratio, a Li6-ZnS scintillate screen that visualizes the radiography image of the sample, and an ultra-night sensitive CMOS Camera. The 25 meV of thermal neutrons that come from the reactor has been used for the experiment. The photograph and drawing diagram of the neutron radiography/tomography facility are shown in figure 2 and figure 3.

For tomography reconstruction, the radiography images from the sample position were collected from 0^{o} to 360^{o} with a step of 0.5^{o}. Each projection image of the sample is captured by the ultra-night sensitive CMOS Camera, and saved to data acquisition computer in 16-bit Tagged Image File Format (TIFF). Before tomography reconstruction, the noise of all the images is removed using the image processing software of ImageJ. Then, the clean projection images are reconstructed using the 2D tomography reconstruction software of Octopus 8.8.

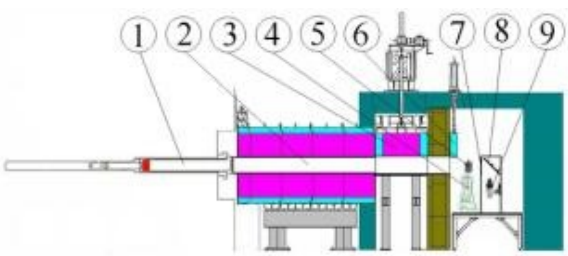


Figure 2. The photograph of neutron radiography **Figure 3**. A Schematic drawing of neutron facility radiography facility: 1. Inner collimator; 2. Outer collimator; 3. Main shutter; 4. Sample table; 5.Sample; 6. Auxiliary shutter; 7. Scintillate screen; 8. Mirror; 9. CMOS camera

In order to compare with the other technique such as X-ray tomography technique, a thermal neutron radiography station at the neutron spallation source SINQ (NEUTRA), PSI, Switzerland that has an optional X-Ray source has been utilized. Figure 4 shows the layout of the NEUTRA. The NEUTRA beamline consists of evacuated neutron flight-tubes looking through a 20 mm diameter pinhole into the D_2O SINQ moderator tank. Outside the SINQ shielding wall at position 1 the optional 320 kV X-ray source can be moved into an irradiaton position. The tube voltage of the X-ray source that was used for the experiments is 120 kV with the exposure time was 15s.for each image.

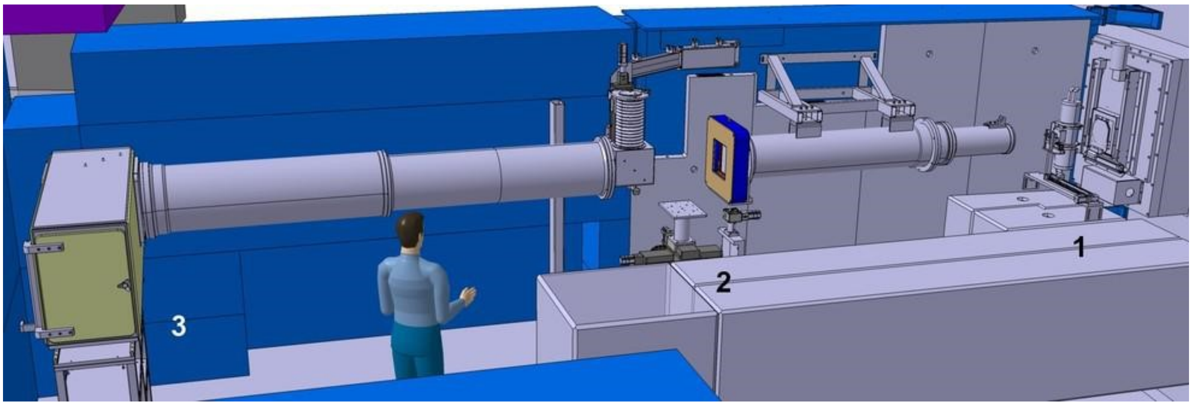
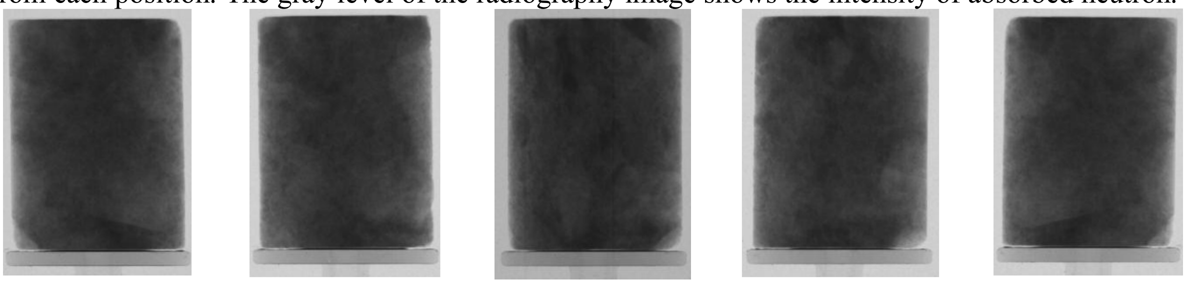


Figure 4. Layout of NEUTRA

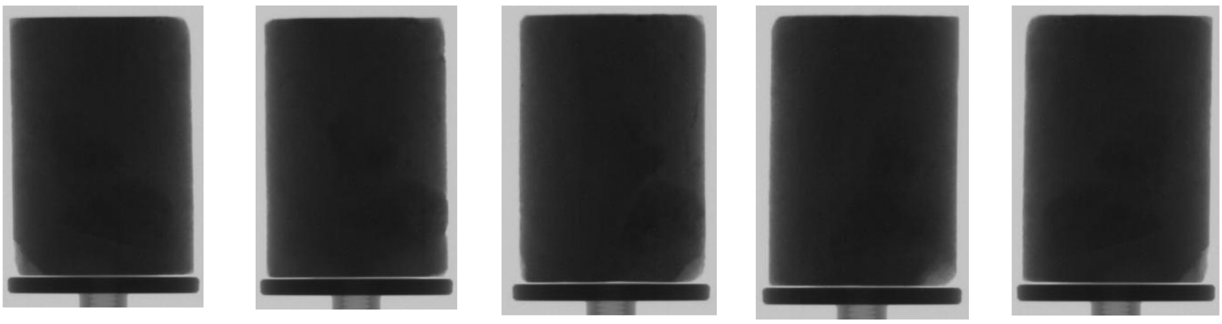
3. Results and Discussions

The radiography images of the limestone that has been acquired at some positions using neutron radiography and x-ray radiography are shown in figure 5 and figure 6, respectively. From these radiography images, the neutron radiography images show materials inside the limestone clearly than the x-ray radiography images. The porosity between materials inside the limestone can be observed from each position. The gray level of the radiography image shows the intensity of absorbed neutron.



0° 45° 90° 135° 180°

Figure 5. The radiography images of the limestone using neutron radiography



0° 45° 90° 135° 180°

Figure 6. The radiography images of the limestone using x-ray radiography

Sliced images of the tomography reconstruction using neutron tomography and X-ray tomography are shown in figure 7 dan figure 8, respectively. From these sliced images, the neutron tomography

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shows the porosity inside the limestone clearly than the X-ray tomography, because the oil consists of hydrocarbon and the hydrogen have almost 1000 times higher mass attenuation coefficient to the thermal neutron than to the x-ray, as shown in figure 9. It means that the oil absorbed the neutrons on the interaction with the materials of the limestone, while almost all X-rays penetrated the porosity occupied by the oil. .

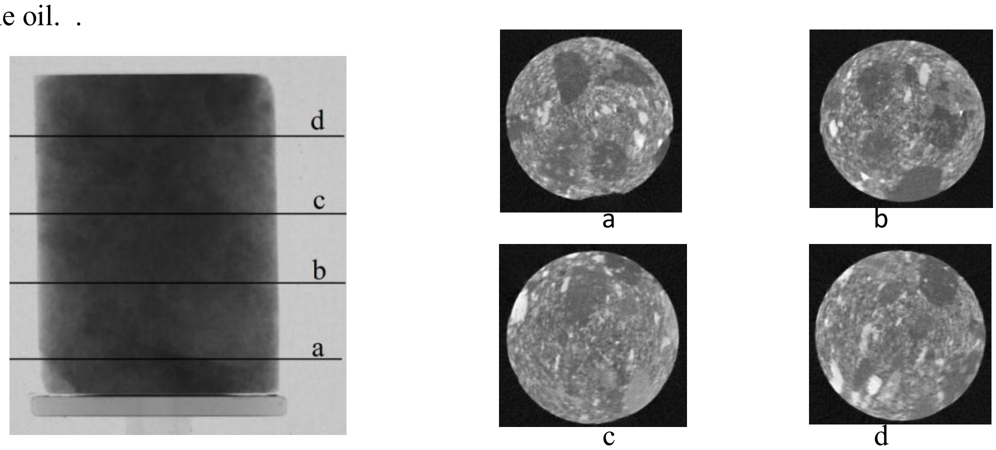

Figure 7. Sliced images of the limestone using neutron tomography

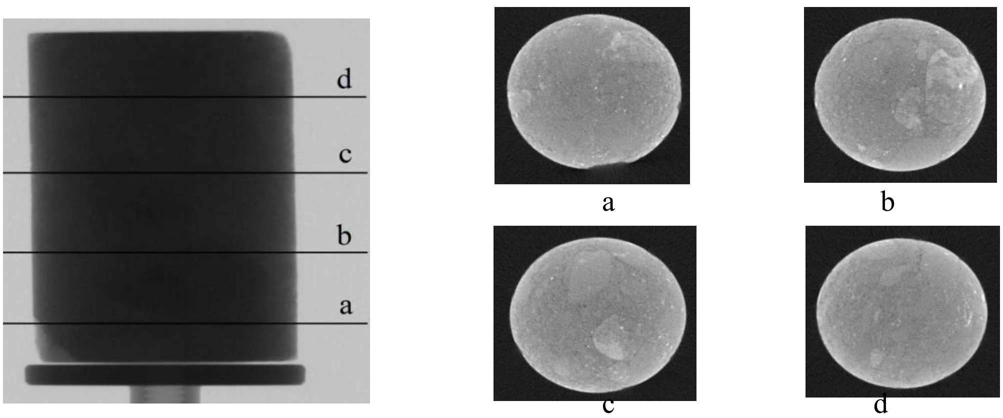

Figure 8. Sliced images of the limestone using X-ray tomography

The darker intensity in the sliced images of neutron tomography shows that the porosity is occupied by the oil, since the oil consists of the hydrocarbon and absorbs the neutron. On the other hand, in the sliced images of x-ray tomography, the porosity that is occupied by the oil can not be observed by x-ray tomography. The maximum pores size of 5 mm^3 has been detected using the porosity analysis software VG Studio, and the volume of the porous is 11.3% of the total volume of the limestone..

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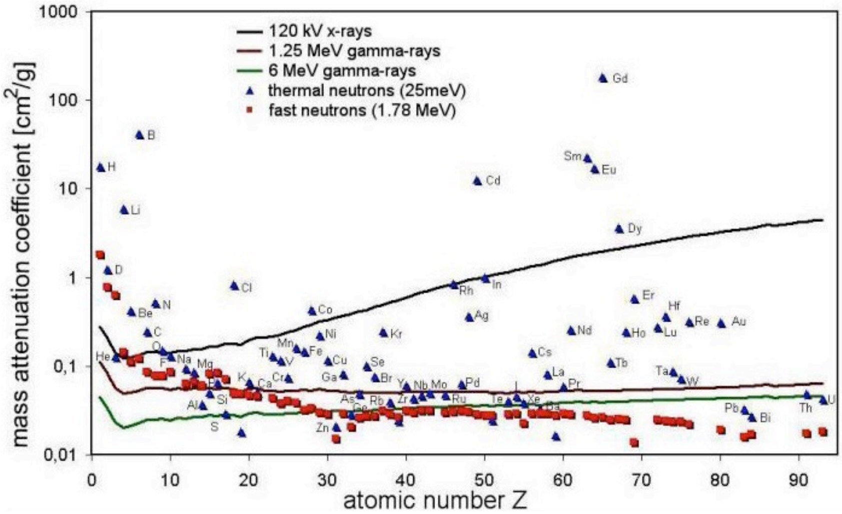

Figure 9. Relationship between mass attenuation coefficients and atomic number [12].

4. Conclusion

Characterization of the porosity inside the limestone has been performed. The porosity that is occupied by the oil can be observed clearly using the neutron tomography technique compared with the x-ray tomography technique. Therefore, the neutron tomography technique is useful for the characterization of the limestone to detect the porosity that is occupied by the oil.

Acknowledgment

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