Isolation Technique for Reconstruction and Visualization of Crack in Geothermal Reservoir Rock

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Aims

This study is a development of previous work conducted by Latief et.al.[1], The aim of this study is to develop both qualitative and quantitative analysis of cracks as one of significant type of pore space inside geothermal reservoir rock. Qualitative analysis can be conducted through visual inspection of 3D images of the sample, while quantitative analysis involves calculation of various properties through computational approach. To be able to perform such analyses, one should be able to first differentiate between the granular type of pore space and the crack or fracture type of pore space inside a sample. Subsequently, calculation of basic petrophysical properties such as volume fraction of crack and specific surface area of the crack can be performed. In the field of computational rock physics, such technology has been vastly employed to provide digital representation of various kind of rock. A number of noteworthy researches are [2-4].

Method

In this study, the sample is a geothermal reservoir rock from West Java, Indonesia (Figure 1, left). The digital data of the rock was obtained by utilizing a µCT scanning device which will later produce three-dimensional image of the rock. Figure 1 (top) shows the µCT scanning device SkyScan 1173 and its control workstation which is installed in the Basic Science Advanced Laboratory, BSC-A Building, Institut Teknologi Bandung, Indonesia. The µCT scanning device is capable of producing high energy X-ray to penetrate such rock with high density.

Figure 1: Left: sample of geothermal reservoir rock. Right: µCT scanning device SkyScan 1173 and its control workstation.

The geothermal reservoir rock has spatial dimension of 3 cm x 3cm x 5 cm. The scanning was performed using 130 kV, current of 61µA, exposure time of 295 ms, rotation step of 0.4°, using 0.25 mm brass filter, and camera resolution of 1120 x 1120 pixels (which corresponds to camera binning of 2 x 2). The scanning and reconstruction process produced images with spatial resolution of 59.85 µm/pixel.

Figure 2 shows the color-coded images produced from the reconstruction process, where the colors indicate pseudo-density of the rock material. Darker areas indicate region with low density, and the darkest one indicate air-filled pore space. In this study, we define volume of interest (VOI) as to produce a box-shaped medium with spatial dimension of 440x440x730 pixels

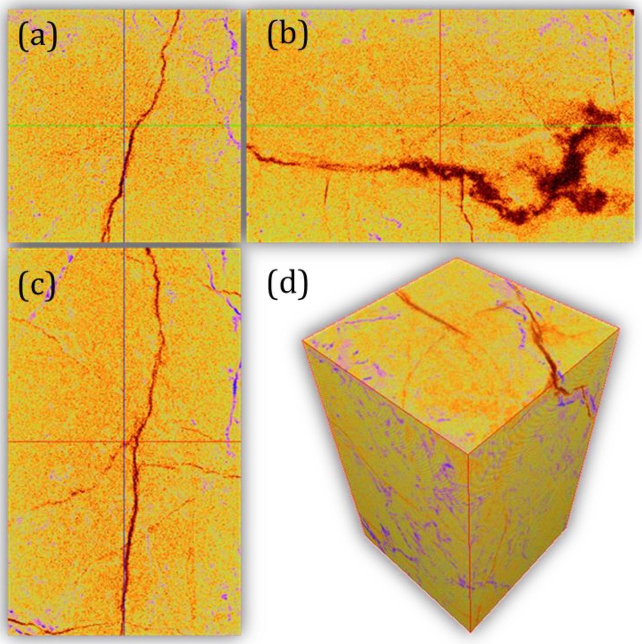

Figure 2: Color-coded pseudo-density images. (a) Transaxial image, sliced at z = 364 (b) Sagittal image, sliced at x = 219 (c) Coronal image, sliced at y = 219 (d) 3D visual of the reconstructed data.

To be able to isolate the crack type of pore space, we must first remove the granular type of pore space. We first binarize the reconstructed images by thresholding at grayscale value of [0 70] (Figure 3). Using the binarized images, we can analyze individual Transaxial slices for the pore size distribution (Figure 3-right, colored area indicates pores with different size). This process is essential so we can estimate which size of the 2D pores that corresponds to granular type of pore space that we would like to remove during the crack isolation by despeckling.

Figure 3: Left: Grayscale image transaxial image sliced at z=730, center: binary image with thresholding level of [0 70], right: color-coded image, based on pore size.

Results

Visualizations of crack were performed using ImageViewer and CTVox. From the color-coded reconstructed images (Figure 2), we can directly visualize the crack without isolating the crack from the granular-type pores. This can be done using CTVox by adjusting the Transfer Function, that is by suppressing the opacity of material with high density (the solid part of the rock), and at the same time enhancing the opacity as well as the luminosity of the regions with lower density (pore space of the rock), we can roughly visualize the pore (see Figure 4). We can further modify the color of certain region by modifying the RGB transfer function. Such enhancement was able to provide us with images that we can use to observe the crack, however, we can still see black spots which are the granular-type pores. Thus to further characterize the sample, we should conduct further process such as to eliminate the granular-type pores.

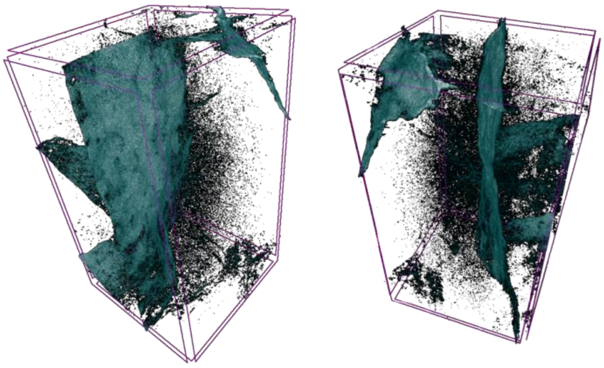

Figure 4: 3D visual of the crack, enhanced by modifying opacity, luminosity and RGB transfer function using CTVox (as reported in [1]).

The most important part of the image processing of the data is crack isolation. From Figure 3-left we can estimate the size we can use as pore size threshold to remove small pores, which corresponds to granular type of pore space. The isolation was done by 2 step despeckling: first one is to remove black speckles (noise that might be identified as solids) using threshold of 20 pixels, and the second one is to remove the white speckles afterwards using threshold of 60 pixels. These white speckles correspond to granular-type pore space. The despeckling process was conducted in 2D space, because if we use 3D despeckling process, some granular type of pore space are not easy to remove because the good connectivity between the pores. Hence we performed the 2D despeckling process for three direction of slices (transaxial, sagittal and coronal). From this process we obtain three sets of images which contains isolated cracks. We combine the three sets of images to obtain a better result. Figure 5 shows comparison of the original binary image (contains granular-type and crack-type pore space) and the post-processed (contains only crack-type pore space).

Basic characteristics of the sample are listed in Table 1.

Table 1: Basic Properties.

Properties	Value
Sample dimension (cm x cm x cm)	3 x 3 x 5
Spatial resolution (µm/pixel)	59.85
Data dimension (pixels)	440x440x730
Total porosity (%)	6.27
Volume fraction of crack (%)	2.79
Surface density of crack (1/pix)	0.02029

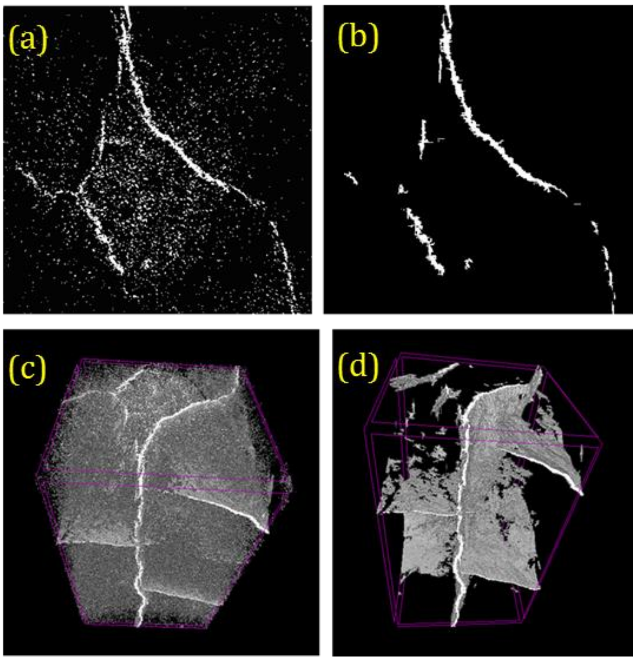

Figure 5: (a) Binary image which contains granular-type and crack-type pore space and (c) its corresponding 3D visual. (b) Preview of isolated crack after 2 step despeckling process and combining 3 sets of images. (d) 3D visual of (b) where cracks are visually enhanced.

Compared to the preliminary study in [1], in this research we were able to recover larger value of volume fraction of crack by 0.44%, and the crack surface density by 0.00162.

Conclusion

By using CTVox, 3D crack visualization can be easily done by modifying opacity, luminosity and RGB transfer function. The visual result however still displays the granular-type pores. Using simple thresholding and despeckling, crack-type pore can be isolated from the granular-type of pore space. We can also notice that the cracks are in the form of intersecting sheets. Basic characterization can be done using image analysis on the binarized image. The total porosity of the sample id 6.27% and the fraction of the cracks is 2.79% from the total volume of the sample, while the crack surface density is 0.02029/pix.

References:

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