Characterization Of Rock Fracture by Digital Image Analysis

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Abstract

Fractures play an important role and determine behavior of fluid flow through porous media, such as oil, gas, and geothermal reservoirs. Identification of fracture characteristics that affect physical properties of rock become important. Characterization of rock fracture can be conducted using digital image analysis method. This method gives quantitative characterization of rock fracture. Fracture characteristics investigated in this research are length, width, orientation, distribution, density, intensity, and fractal dimension. Fractal dimension is calculated by box-counting method.

In this study, characterization was performed on digital image of rock samples and outcrop walls fracture pattern that are collected from Lembang fault, in West Java. It is observed that dimension of both rock samples and outcrop walls are fractal. Fractal dimension for these two groups show similar value. Fractal dimension of outcrop walls are larger than that of rock samples. Fractal dimension of rock samples range from 1.10 to 1.13 and fractal dimension of outcrop wall varies from 1,13 to 1,17. The data also show that fractal dimension is in direct relation with fracture density.

Key words: *characterization, digital image, fractal dimension, fracture.*

Abstrak

Rekahan mempunyai peranan penting dan menentukan kelakuan aliran fluida dalam media berpori seperti sumur minyak, gas, dan geothermal. Mengetahui karakteristik rekahan yang mempengaruhi sifat fisik batuan menjadi penting. Karakterisasi rekahan batuan dapat dilakukan dengan analisis citra digital. Metode ini memberikan karakterisasi kuantitatif terhadap rekahan batuan. Karakteristik yang ditentukan disini adalah panjang, lebar, orientasi, distribusi, densitas, intensitas, dan dimensi fraktal. Dimensi fraktal dihitung dengan metode box-counting.
Dalam penulisan ini karakterisasi dilakukan terhadap citra pola rekahan sampel batuan dan dinding singkapan yang diambil di sesar Lembang, Jawa Barat. Hasil menunjukkan bahwa dimensi rekahan batuan dan dinding sigkapan tersebut adalah fraktal. Dimensi fraktal cenderung sama untuk kedua kelompok sampel dan dimensi fraktal sampel dinding singkapan lebih besar daripada dimensi fraktal sampel batuan. Nilai dimensi fraktal sampel batuan berkisar dari 1,10 sampai 1,13, sedangkan dimensi fraktal sampel dinding singkapan dengan selang 1,13 sampai 1,17. Data juga menunjukkan bahwa dimensi fraktal rekahan batuan berbanding lurus dengan densitas rekahan.

Kata kunci : *citra digital, dimensi fraktal, karakterisasi, rekahan.*

1. Introduction

Porous media are encountered in many branches of science and technology, from agricultural, chemistry, geophysics, civil and petroleum engineering, to food technology. With the advent of precise instrument and new experimental technique, it has become possible to measure physical properties of porous media and flow process therein. But, whether we like it or not, we have to accept the fact that many natural porous system are fractured (Sahimi, 1995). Information about fracture properties is needed in many fields. The number of oil and gas field in which fractures are recognized as playing a major role has risen in recent years (Nelson, 1985). Reserves of geothermal reservoirs depend mainly on the porosity of the rock matrix while steam and water production rates primarily depend on fractures (Li, 2003). In geotechnique, rock strength around borehole can be estimated from

fracture dimension on borehole wall. So, identification of fracture characteristics becomes important. Fracture characteristics investigated in this research are length, width, orientation, distribution, density, intensity, and fractal dimension. Fractal dimension is calculated by box-counting method.

In this study will be designed a software or program for fracture characterization by digital image analysis. This method has some advantageous such as direct measurement and quantitative information. The program then used to characterize natural fracture pattern. Fracture characteristics such as length, width, orientation, density, intensity, and fractal dimension. Rock and outcrop walls fracture pattern from Lembang Fault in West Java are used in this study.

2. Theoretical Background

Fracture characteristics that will be calculated in the program are length, width, orientation, distribution, density, intensity, and fractal dimension. Fractal Dimension in the program is calculated by using box-counting method according to the following relationship:

$$N = \frac{1}{s^D} \qquad (1)$$

where N is the member of boxes fill with fractures, s is the side length of square box, D is the fractal dimension of the fracture pattern. The number of boxes entered by the line of fracture $N(1/s)$ is plotted against the inverse of side length of box $(1/s)$ on the double logarithmic graph. D is estimated from the slope of the regression line of data points using least-square fitting method.

$$\text{Fracture Intensity} = \frac{1}{A}\sum_{i=1}^{N} l_i \qquad (2)$$

where l_i is the length of ith fracture and A is the area of photograph.

$$\text{Fracture Density} = \frac{A_f}{A} \qquad (3)$$

where A_f is the total area of fracture surface.

3. Experimental procedures
3.1 Software Design

Image handling processes such as incorrect image taking, image converting and transmitting, or noise can make quality of that image lower. Any images like this need to improved to make them more usable and more interpretable. In this study, improvement technique is to make fracture pattern easier to see more distinguishable from other part of rock. So, the program provides image improvement techniques such as brightness adjustment and histogram equalization.

Image processing applications such as image thresholding, edge detection, and color inverting are also available in the program. These applications are to generate an image with specific format that is needed in calculating fractal dimension of rock image using box-counting method.

3.2 Validation

The program has been validated by performed characterization to samples from one reference (Figure 1). Sofware display and result of characterization is shown in figure 2 and 3. Comparison of fractal dimension calculation between the program and the reference is shown in table 1.
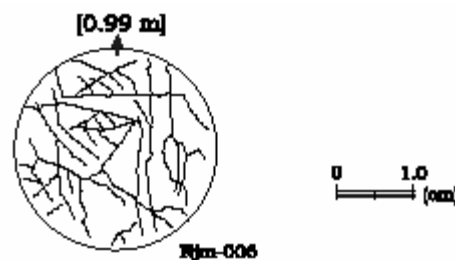

Figure 1. Fractures on bore sample. Solid lines indicate fractures (Nakamura, 2001).
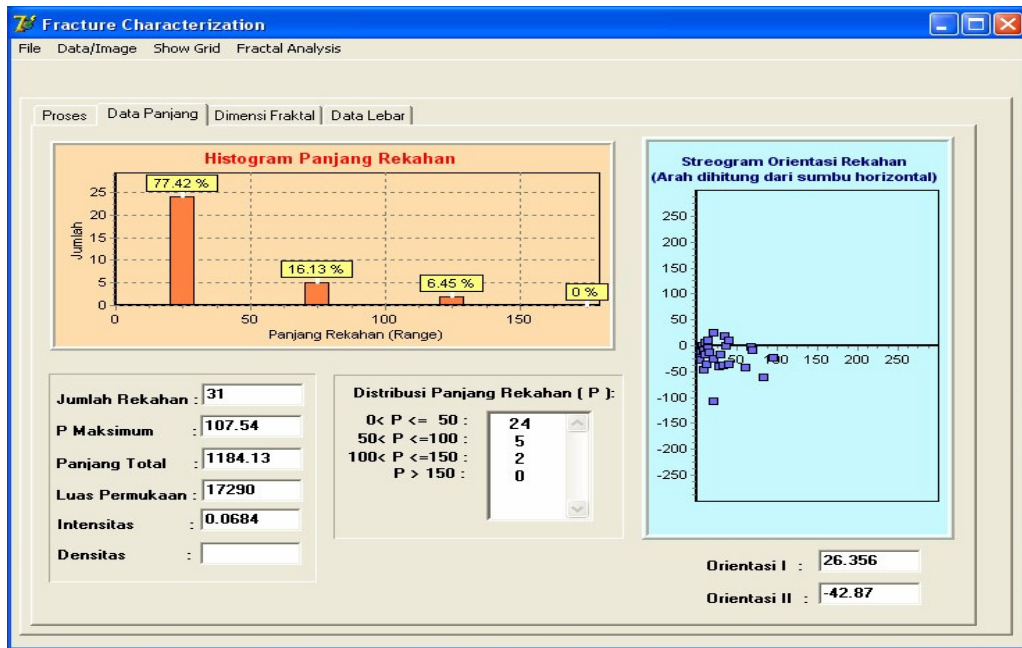
Figure 2. Display of characterization program for Njm-006 sample.
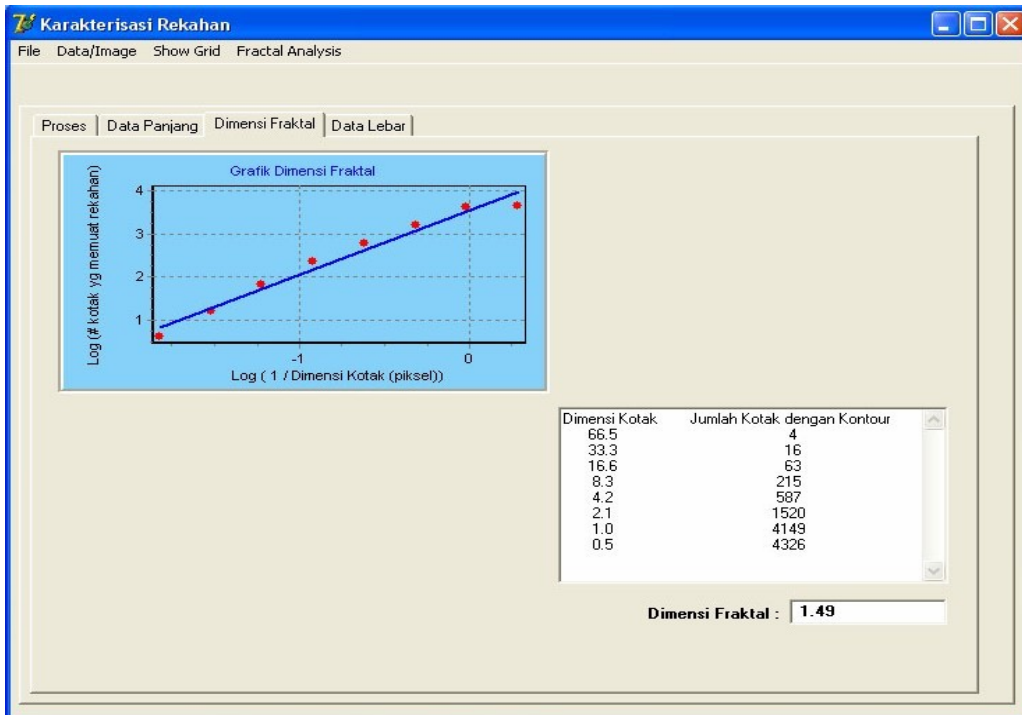

Figure 3. Display of fractal analysis program for Njm-006 sample

Table 1. Comparison of fractal dimension calculation between the
program and the reference.

Sample	Fractal Dimension (Result of reference)	Fractal Dimension (Result of the program)
Njm-001	1,09	1,16
Njm-002	1,21	1,22
Njm-004	1,24	1,31
Njm-005	1,47	1,47
Njm-007	1,41	1,45
Njm-006	1,50	1,49

4. Result and Discussion

In this study, the program was used to characterize sample of rocks and outcrop walls were collected from Lembang Fault in West Java. Four photograph of rocks and outcrop walls were taken randomly. Fracture trace of rocks and outcrop walls samples are given in figure 4 and 5. These patterns were generated using an image processing applications that are available in the program. Fractal dimension and fracture density of all samples are given in table2. It was observed that dimension of both rock samples and outcrop walls are fractal. Fractal dimension for these two groups show similar value. Fractal dimension of outcrop walls are larger than that of rock samples. Fractal dimension of rock samples range from 1.10 to 1.13 and fractal dimension of outcrop wall varies from 1,13 to 1,17. The data in table 2 also show that fractal dimension is in direct relation with fracture density.
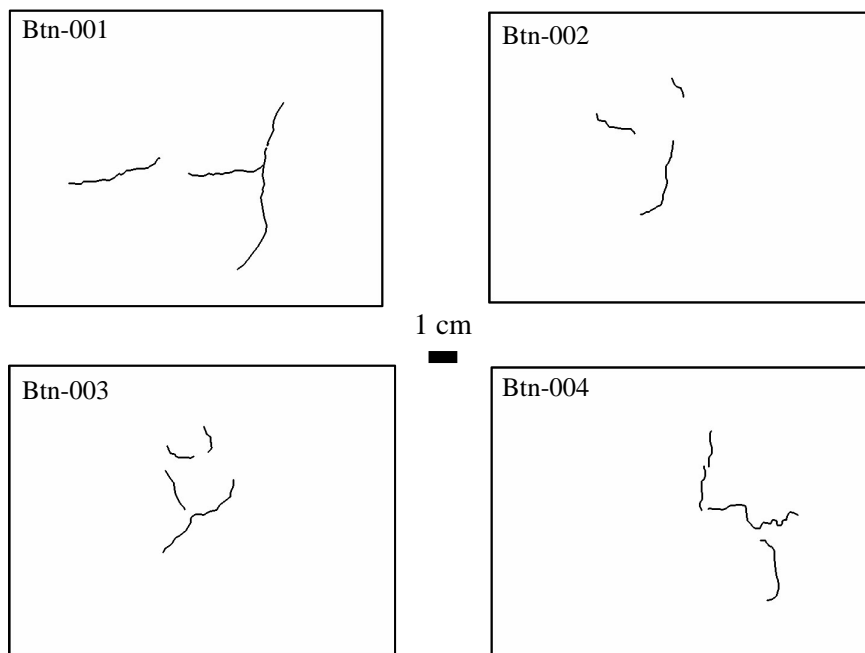

Figure 4. Fracture trace of rock samples that are collected from Lembang Fault
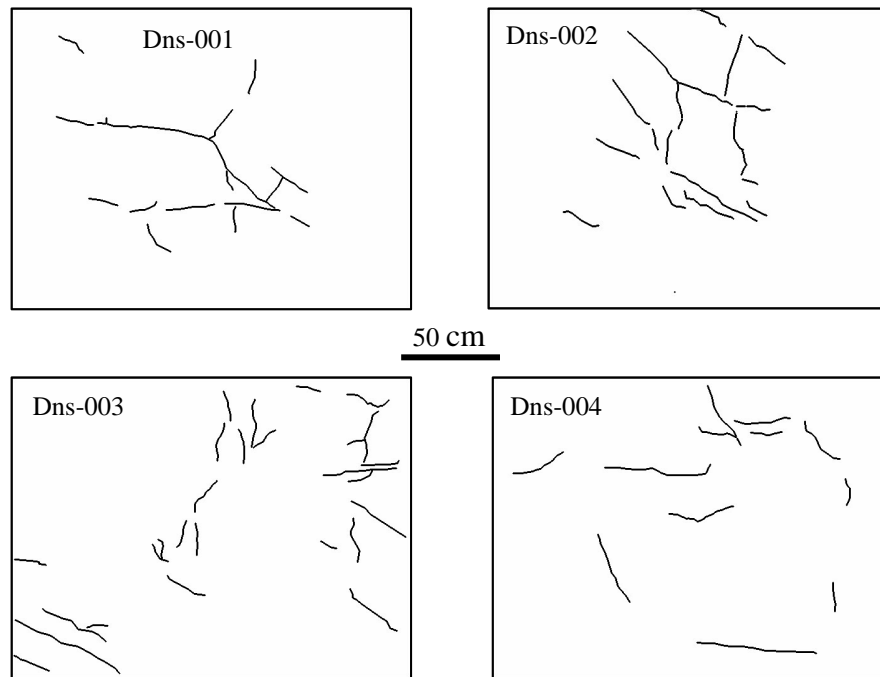in West Java .

Figure 5. Fracture trace of outcrop wall samples that are collected from
Lembang Fault in West Java .

Table 2. Fractal dimension of all rock and outcrop wall
samples that are collected from Lembang Fault in West Java

No.	Sample	Fractal Dimension	Density
1.	Btn-001	1,13	0,0121
2.	Btn-002	1,11	0,0100
3.	Btn-003	1,10	0,0088
4.	Btn-004	1,10	0,0088
5.	Dns-001	1,17	0,0165
6.	Dns-002	1,13	0,0132
7.	Dns-003	1,26	0,0211
8.	Dns-004	1,16	0,0152

5. **Conclusion**

From this research, the following conclusion can be drawn:

(1) Digital image analysis method offers an alternative method in rock fracture characterization. This method gives quantitative result.

(2) Fractal geometry gives useful way to analyze complex structure of rock fractures.

(3) Dimension of rocks and outcrop walls fractures were fractal.

(4) Fractal dimension for these two groups show similar value. Fractal dimension of outcrop walls are larger than that of rock samples.

Fractal dimension of rock samples range from 1.10 to 1.13 and fractal dimension of outcrop wall varies from 1,13 to 1,17.

(5) The data also show that fractal dimension is in direct relation with fracture density.

6. References

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