Fractal Fracture Surface and Its Effects on Fluid Displacement Efficiency

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Fractal geometry has been shown as a proper tool recently for the quantitative characterization of surface topography of rock fractures. In this paper we first presented the design of an apparatus to map the roughness of core size fracture surfaces and fractal analysis of the surface data acquired through this device. Different types of naturally and synthetically fractured rock samples were used during the measurements. Secondly, the transport behavior of single fracture was related to the fractal dimension of fracture surfaces after applying invasion percolation simulations on the synthetically generated representative surfaces.

The device was designed to quantify the surface topography by measuring the elevations on the fracture surface with 1 and 0.1 mm sensitivity in x-y and z directions, respectively. The measurements were achieved by counting the traveled distance of a needle between a fixed point and fracture surface. The surface elevation data collected through this device were used to measure the fractal dimension of natural fracture surfaces and the aperture between two walls. Power spectral density, roughness-length measurement and variogram analysis were employed for this purpose. Power spectral density method yielded considerably lower fractal dimensions than those obtained by other two methods for naturally fractured surfaces. The methods yielded more consistent fractal dimension values for synthetically fractured rock samples.

Invasion percolation simulations were applied on the synthetically generated fractional Brownian motion surfaces with different fractal dimensions. It was observed that increasing surface fractal dimension (or increasing roughness) causes less efficient displacement and lower fractal dimension of the surfaces yields more compact cluster of injected fluid.