Fluid-Flow, Resistivity and Elastic Wave Velocity Simulation of Digital Rock Fracture and Comparison with Experimental Data

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Fluid-flow in the fracture plays a key role to evaluate the mechanism of earthquake and fractured reservoirs (e.g., geothermal and shale) since fracture flow constrains the fluid-flow behavior and rock strength under the ground. To predict the fluid-flow and its distribution under the ground, geophysical explorations (seismic and electromagnetic methods) have been broadly applied. However, there is no established rock physical model to estimate the fluid-flow properties (e.g., permeability) in the fracture from resistivity or elastic wave velocity, and thereby fluid-flow behavior in the fracture are difficult to be precisely interpreted by geophysical explorations. For the better interpretation of these exploration data, more detailed investigation about the effect of fluid-flow behavior on resistivity and elastic wave velocity of fractured rocks is required. In this study, in order to discuss this effect, we measured and calculated them by using fractured rock samples which have different apertures.

We conducted laboratory fluid-flow testby using fractured Inada granite (50 mm in a diameter, 80 mm in a length) which have single tensile fracture with different aperture. For the numerical model, we digitalized this real rock fracture (0.1 mm grid resolution) to calculate fluid-flow, resistivity and elastic wave velocity under the same condition with experiment. Three dimensional fracture flow was simulated by using Lattice Boltzmann Method and we applied Finite Element Analysis to calculate resistivity and elastic wave velocity after this fluid-flow simulation.

As a result, permeability decreases with pressure increase under laboratory experiment and calculated permeability also shows the decrease as the aperture increases. This agreement suggests that fracture permeability is constrained by aperture closure due to the pressure effect. From the permeability matching approach, we found that permeability dramatically decreases after the fracture contact area exceeds ~80%. At this threshold value, fluid-flow path, resistivity and elastic wave velocity show inflections. Our results suggest that permeability change caused by aperture closure could be estimated by seismic and electromagnetic explorations.

Keywords: digital rock physics, elastic wave velocity, resistivity, fracture flow, Lattice Boltzmann Method

