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低温水流入に伴うき裂開口幅変化の数値解析
The numerical study for behavior of fracture aperture associated with cold fluid flow

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Power generation of geothermal power plant sometimes decreases due to reduction of reservoir pressure. Reinjection of used geothermal fluid/cold fluid into the reservoir is conducted in several geothermal power plant to keep/recover the reservoir pressure. It is required for recharge of reservoir pressure that appropriate condition of reinjection in terms of injection pressure, amount of injected fluid, and heat balance. On the other hand, it is empirically observed at some of the geothermal field that amount of injected fluid increases when lower temperature fluid is injected. In this research, we investigated relationship between temperatures of cold fluid and fracture aperture, using numerical simulation.

We conducted numerical simulation for the change in fracture aperture when cold fluid flows into the fracture, using 2D FEM code ″ GEOCRACK2D ″ (Swenson et al., 1995). We set the condition that cold fluid was injected into a single fracture within high temperature rock mass. In this simulation, cold fluid flowed from center of fracture to edge of fracture. Fluid pressure was 1 MPa at center of fracture and 0 MPa at edge of fracture. This given pressure condition made fluid flow from center of fracture to edge of fracture. Initial temperature of rock mass was 300 ℃ and that of cold fluid was 100 ℃. Initial stress condition was 20 MPa in x direction and y direction.

As a result of simulation, the fracture aperture increased with time although 20 MPa of normal stress worked on the rock mass and fluid pressure was at most 1 MPa. It was also simulated that the rock mass around the fracture was cooled down by cold fluid and cooled area extended with time. Normal stress on the fracture decreased. The area where normal stress decreased extended over time.

These results can be interpreted that cooling of rock mass by cold fluid caused thermal shrinkage of rock mass, which decreased normal stress on the fracture surface. Finally, the fracture aperture became large, suggesting increasing in permeability.

We also conducted the simulation for the effect of difference in initial temperature between rock mass and cold fluid. We compared the change in fracture aperture about four temperature difference conditions. Fluid flow, fluid pressure, temperature of rock mass and initial stress condition were same with first simulation. Temperature of cold fluid was 100 ℃, 150 ℃, 200 ℃ and 250 ℃.

As a result of simulation, the fracture aperture increased drastically when the temperature difference between rock mass and cold fluid was bigger than 150 ℃. The fracture aperture slightly increased when the temperature difference is smaller than 100 ℃. The bigger temperature difference was, the earlier fracture aperture opened. The results of simulation suggested that there was the critical value in temperature difference between 100 ℃ and 150 ℃. It was summarized that the fracture aperture increased and that the fracture permeability became large when the temperature difference was bigger than the critical temperature difference.

キーワード: 地熱貯留層, き裂, き裂開口幅, 熱弾性, 熱収縮, 熱水還元・涵養
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