Fundamental study on hydraulic fracturing simulation with DEM under high pressure and temperature condition

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One of the most attractive topics in geothermal development is the realization of enhanced geothermal systems (EGS) in ductile zones. Thermal energy extraction from hot dry rock may require hydraulic fracturing through rocks in ductile zones, where rocks are supposed to deform in a ductile way due to the high pressure and high temperature (HPHT) conditions. One of the key factors in its realization is, therefore, to understand their mechanical behaviors of ductile rocks and of hydraulically created fractures under the HPHT condition, which have not been well investigated in the past.

Numerical simulations are widely accepted as one of the effective approaches to understand the mechanism of hydraulic fracturing, and numerical studies taking cooling effects from injected fluid on hydraulic fracturing into consideration have been conducted. Though distinct element methods (DEM) are frequently used to understand brittle failure or ductile deformation mechanism of rock in biaxial or triaxial compression tests, hydraulic fracturing simulations including both ductile behaviors and cooling effects due to injected fluid in the HPHT environment has not been fully investigated yet. Since the mechanical response to the fluid injection shows drastic changes at the brittle-to-ductile transition condition, incorporation of the transition behavior of granite into DEM is an essential step.

In this study, we demonstrated a series of hydraulic fracturing simulations with degradation approaches for the bond properties in DEM, i.e. bi-linear approximation model and degradation model, to replicate semi-brittle or ductile behavior at the HPHT condition including hydro-thermo-mechanical model. The numerical simulation results showed that results from bi-linear approximation model, which is suitable for replicating ductile behavior of granite, were consistent with laboratory experiment results under the HPHT condition. We can observe the cooling effect of rock mass due to injected fluid, while a considerable interaction between solid and fluid cannot be observed due to the shortness of injection time.

キーワード：水圧破砕シミュレーション、個別要素法、延性、固体ー液体ー熱連成モデル、高温高圧、地熱開発
Keywords: Hydraulic fracturing simulation, Distinct Element Method, Ductility, Hydro-Thermo-Mechanical model, High Pressure and High Temperature, Geothermal Energy Development

