STT13-23 Room:102A Time:May 28 16:45-17:00

Fracture propagation stimulated by hydraulic injection under in-situ stress field

OKUBO, Kurama[1*] ; MIKADA, Hitoshi[1] ; TAKEKAWA, Junichi[1]

[1]Kyoto University

Hydraulic fracturing is a major scheme for improving the production of non-conventional energy resource as well as horizontal well. It increases the permeability of reservoirs which is usually tight and low permeability by making fracture net in the reservoirs. Acoustic Emittion (AE) is observed on the ground surface or in observation wells to monitor the expansion of the fracture net by fluid injection. Laboratory experiments indicate that hydraulic fractures would propagate in the direction of the maximum principal stress around the fractures. Hence it is assumed that in-situ stress could play an important role for the behavior of hydraulic fracture propagation in the field scale. It is, however, difficult to observe the fracture propagation directly due to the depth of the reservoir layer (>2km generally). Therefore, the ratio of tensile crack to shear one induced by the fluid injection has not been revealed yet.

Distinct element method (DEM) has often been applied to the simulation of the hydraulic fracturing, which shows the fracturing mechanism around the injection well, while it has a limit of analytical area around the borehole due to the computational cost. It is, therefore, challenging to simulate hydraulic fracturing in the real scale (>10m). In this study, we adopted the extended finite element method (X-FEM) and add a new degree of freedom for the effects of the fluid inside the fracture (Chen 2013). We optimized this scheme to simulate the fracture propagation in the large scale under in-situ stress field. The advantages of this scheme are following. a) Fractures are defined independent of the mesh, which could reduce the computational cost due to the re-meshing process. b) It maintains the continuity of displacement at each node on the elements. It would bring stable stress field and fracture simulations. We developed the hydraulic fracturing simulation tools with this scheme and explored the mechanism of fracture propagation triggered by the fluid injection.

For the evaluation of the fracture propagation, we made a simulation model in real scale and put external forces as in-situ stress. The aim of this simulation is to investigate the influence of the in-situ stress on the fracture propagation and fracturing mechanics. To understand the effect of the stress field around the fracture tip, we also created a heterogeneous model of P-wave velocity. We conducted two simulations with the homogeneous and heterogeneous models, and obtained the characteristics of the fracture propagation in the geological formation.

The first result, using the homogeneous model, shows that fracture propagates with not only tensile but also shear stress components even if the injected fluid inside the fracture presses outward. It suggests that hydraulic fractures could generate mixed-mode crack. The second result from the heterogeneous model simulations indicates that the in-situ stress field could be disturbed by the heterogeneity and the fractures no longer propagate simply in the direction to the maximum principal stress from far field. It indicates that while fractures propagate in a linear fashion in the homogeneous model, they propagate in a turbulent manner in the heterogeneous model.

We investigated the influence of the in-situ stress field on the hydraulic fracture propagations in the geological layer. It is suggested that the hydraulic fractures would propagate with both tensile and shear crack that is mixed-mode cracks. In addition, the macroscopic heterogeneity in the subsurface could affect the behavior of the microscopic fracture propagation. These results might help to estimate the radiation of the AE and evaluate the fractured reservoir in the real field.

Keywords: Hydraulic Fracturing, X-FEM, In-situ stress, Fracture propagation