Numerical modelling of fluid-induced fault slip reactivation, application to Geo-Energy systems

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Introduction

Geoenergy is one of the most promising techniques to exploit renewable energy resources from the Earth in order to limit emissions of greenhouse gas. Deep geothermal exploitations are associated to long term fluid circulation and pressure perturbations at great depth, in fractured and faulted zones with possible connections to the basement and are likely associated to a risk of triggering earthquakes and inducing seismicity.

In this research, the influence of stress state and fluid injection rate on the reactivation of pre-existing faults are simulated by the Finite Element Method (FEM, ABAQUS). We conduct numerical model on experiments(Passelègue, Brantut, and Mitchell 2018) of rock specimen with a pre-existed penetrating crack under triaxial stress conditions. Fault reactivation is triggered by injecting fluids through a borehole directly connected to the fault.

Method

The 2D rock sample with the pre-existing fault is established. The studied specimen is 40mm in width and 100mm in height, which is cut into two separated halves by a through crack with an angle of 60 degrees from the horizontal to simulate the pre-existing fault. Injection-triggered earthquakes are caused by an increase in pore pressure (Sun, Yang, and Zhang 2017). The pore pressure diffusion (Sergei A. Shapiro, Huenges, and Borm 1997; 1999; 2000) along the fault is governed by the equation

$$\frac{\partial p}{\partial t} = D \cdot \nabla^2 p$$

Where t indicates the time of fluid injection and D is the pore pressure diffusion coefficient, which usually between $10^{-4}$and $10^{-1}m^2/s$ for rock (Talwani and Acree 1985).

Results

Result of fluid diffusion along the fault using the finite difference method by Almakari (2019)'s code is presented in Fig. 1(a).

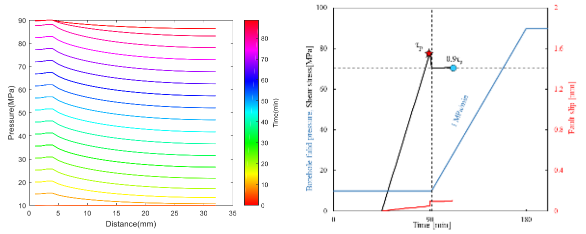

Figure 1 (a) Fluid diffusion (b) Numerical results

The result of shear stress and fault displacement is shown in Fig. 1(b). The injection pressure at the onset of fault reactivation is 25.6MPa, which is higher than that of uniform fluid pressure. The effective stress along the fault with diffusion is lower than that of injection point, and the effective stress under uniform pressure equals the injection point. Therefore, the results obtained are closer to the experimental results.

Conclusion

The onset of fault reactivation is observed when the fault slip begins. The results show that fluid pressure concerning diffusion decreases the effective fluid pressure along the fault and modifies the injection pressure at the onset of fault reactivation.

Reference

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