COUPLED MECHANICAL AND HYDRAULIC LABORATORY EXPERIMENT OF SHEARING ON GRANITE FRACTURE

Takuya ISHIBASHI[1] and Hiroshi ASANUMA[1]
[1]Fukushima Renewable Energy Institute, AIST, 2-2-9 Machiikedai, Koriyama, Fukushima, 963-0298, Japan
e-mail: takuya.ishibashi@aist.go.jp

ABSTRACT

Hydraulic stimulation on the geothermal reservoir is the well-known operation for improving the transmissivity and fracture connectivity within the reservoir. In this operation, by increasing pore pressure, shear slip on pre-existing fractures are triggered or new fractures generate from the tips or the middle of pre-existing fractures. Thus, the mechanical and hydraulic properties of fracture/fracture network are strongly coupled during the stimulation, but it is not well quantified how these properties are coupled. Here, we conduct the laboratory experiments to concurrently monitor the mechanical and hydraulic properties during the hydraulic shearing of rock fracture, which is similar to the naturally observed fracture having rough surfaces, at high stress state. Through the experiments, we find the shear slip is limited to 0.16% of the representative length of pressurized area, and the fracture permeability increases about 8 times of the initial permeability (before slip). Interestingly, fractures are newly propagated from the middle of the pre-existing fracture's surface and these fractures possibly have significant roles on both mechanical and hydraulic properties of the fracture.

Keywords: EGS, rock fracture, laboratory experiment, shearing, permeability, acoustic emission

1. INTRODUCTION

Hydraulic stimulation on the geothermal reservoir is the well-known operation for improving or maintaining the transmissivity and fracture connectivity within the reservoir (Guglielmi et al., 2015). In this operation, by injecting pressurized water into the reservoirs, pre-existing fractures are reactivated in shearing mode with the opportunity for self-propping on asperities. Due to these mechanisms, mechanical and hydraulic properties of fracture/fracture network evolve. During the shear slip on fractures, seismicity is possibly increased (Majer et al., 2007), and it is necessary to be explored how the mechanical and hydraulic properties are coupled in each other during the hydraulic shearing.

With this in mind, the present study explores the coupling between mechanical and hydraulic properties of granite fracture during hydraulic shearing via the laboratory experiments. In our study, by recording the acoustic emissions (AEs), the novel concurrent monitoring is possibly realized. Based on the experimental results, we discuss how we can apply the laboratory experimental results to the field scale (mesoscale) problems.

2. METHODS

We conduct experiments to concurrently monitor the evolution of mechanical and hydraulic properties of granite fracture during shear slip triggered by the pressurized water injection. We use the experimental system installed in FREA, AIST in 2016 (see Figure 1a). Experiments are conducted on the cylindrical sample (50 mm in diameter and 100 mm in length) of Inada granite (Ibaraki, Japan) with a single tensile fracture. Confining stress, which corresponds to σ_2 and σ_3, is set to 18 MPa and is kept constant during the experiment. Both inlet and outlet fluid pressures are set to 0.5 MPa at this point. Then, axial load is increased and set to a constant value of 300 kN (σ_1 = 150 MPa). Once such a critically stressed state of fracture has been achieved, we inject the fluid to the fracture vie the borehole (Figure 1b) and pressurize the fluid to trigger the shear slip. During this process, the mechanical and hydraulic properties of fracture and associated AEs are concurrently monitored with high precision.

3. RESULTS

Shear slip is triggered on the fracture when the inlet pore pressure reaches to 17.5 MPa. This situation can be explained well by considering the Mohr-Coulomb failure criteria. The critically-stressed fracture is sheared by around 85 μm (0.16% of the representative length for the pressurized area) and the fracture permeability increases from 1.2×10^{-12} m^2 to 9.3×10^{-12} m^2 (around 8-folds) due to the hydraulic shear slip. Different from the hydraulically induced shear experiment conducted at relatively low stress state (see *Ishibashi et al.* (2018) for detail), we find that fractures are newly propagated from the middle of the pre-existing fracture's surface (Figure 1b) and these fractures possibly have significant roles on both mechanical and hydraulic properties of the fracture. Such fracture propagation will be taken into account in the future simulation for EGS designing.

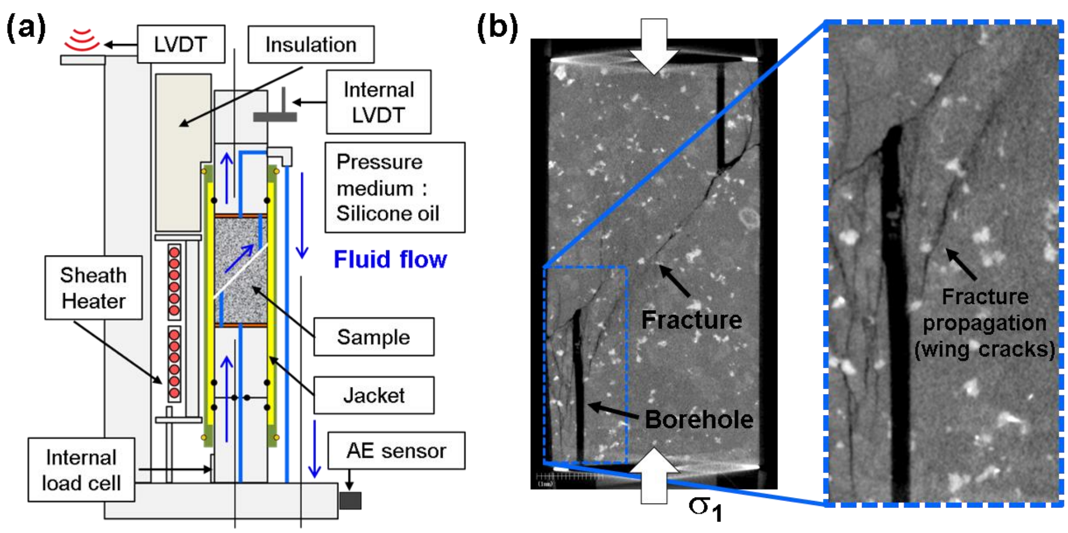

Fig. 1 (a) Experimental system for shear-flow coupled experiment under high pressure and high temperature conditions. This system is installed in Fukushima Renewable Energy Institute, AIST, in 2016. (b) Internal structure of cylindrical fractured granite sample after shearing, which is triggered by pressurized water injection. This image was obtained by using the microfocus X-ray CT scanner (Scan Xmate D225RSS270, Comscantecno) at Tohoku University.

4. CONCLUSIONS

- We realize the concurrent monitoring of hydraulic and mechanical properties of granite fracture during the hydraulically induced shearing at relatively high stress state.
- We try to quantify the slip distance and the associated permeability enhancement of fracture during the injection induced shearing based on the laboratory experiment.
- We point out the fracture propagation from the middle (or tips) of the pre-existing fracture should be considered in the future simulation for EGS designing.

ACKNOWLEDGEMENTS

The authors thank Miki Takahashi and Noriaki Watanabe for their valuable suggestions in developing the experimental system. The present study was supported in part by METI, Japan through International Research Program for Innovative Energy Technology. This support is gratefully acknowledged.

REFERENCES

Guglielmi, Y., Cappa, F., Avouac, J. P., Henry, P., and Elsworth, D. (2015): Seismicity triggered by fluid injection-induced aseismic slip, *Science*, **348**(6240), pp. 1224-1226.

Ishibashi, T., Asanuma, H., Ishikawa, S., and Watanabe, N. (2018): Concurrent monitoring of hydraulic and mechanical properties of granite fracture during hydraulically induced shearing in laboratory, *Proceedings of 52nd US Rock Mechanics/Geomechanics Symposium*, ARMA 18-369.

Majer, E. L., Baria, R., Stark, M., Oates, S., Bommer, J., Smith, B., and Asanuma, H. (2007): Induced seismicity associated with Enhanced Geothermal Systems, *Geothermics*, **36**(3), pp. 185–222.