Relationship between rock deformation and permeability evolution during fracturing in rocks for CCUS technology

*Takashi Fujii[1], Xinglin Lei[1], Masao Sorai[1]

1. National Institute of Advanced Industrial Science and Technology

An understanding of relationship between fluid flow transport and geo-mechanical response within geological reservoirs is of a fundamental concept for a suitable utilization of deep underground repositories (e.g., Carbon Capture and Storage (CCS), Carbon Capture Utilization and Storage (CCUS), shale gas exploration). Particularly, fracture permeability within caprocks plays an important role in producing hydrocarbon during the trapping of buoyant gas fluids in reservoirs for CCUS projects. Wide variations of permeability value depending on rock deformation (including fracturing process) for several types of rocks has been determined using the coupled fluid flow transport (TOUGH2) and geo-mechanical response (FLAC3D) simulator (e.g., Rutqvist et al., 2002) so far. However, the evolution of permeability during fracturing in such rocks is very complex, and there now are being reported few constitute law for the linked deformation and fracture permeability. Furthermore, few laboratory studies have experimentally been conducted so as to replicate this process by simultaneously fracturing specimens and measuring permeability at in situ fracturing stress states (Carey et al., 2015; Fujii et al., 2015; Frash et al., 2016).
The purpose of this study is to investigate experimentally permeability change during fracturing in (i) caprocks (shale, mudstone, slate) and (ii) reservoir rock (sandstone, tuff), the conditions of which assumes that CO_2 is injected into geological media. We attempt to fit a model to obtained experimental data (i.e., permeability: K, volumetric strain: e_v) in order to develop suitable constitute law for the optimize use of coupled geo-mechanics and fluid flow simulator.
Our results demonstrate that there could mainly be classified into the two patterns of relationship between e_v and K of all materials tested. Particularly, it is apparent that the permeability behavior throughout fracturing and slipping processes are quite different between rock groups of (i) and (ii). Caprocks have a sharp-jumped increase of permeability during fracturing in the rock matrix, but reservoir rocks have significantly smaller permeability change, compared to the caprocks in post-failure regime. Furthermore, model fitting results suggest that the relationship between e_v and K of all materials tested could be explained fully by modification of conventional model (e.g., Cappa et al., 2009)
In light of findings of our study, it can be concluded that the propsed constitute law might be contributed to the simplification and optimization of the coupled fluid flow and geomechanical simulator.

Keywords: rock deformation, fracture permeability, Constitute law

