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Effect of Fracture Surface Damage on Fluid Flow and Transport in Geo-reservoirs

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SUMMARY

This study quantifies the effect of fracture surface damage caused by secondary processes during CO2 injection on fluid and gas flow and transport in sandstone geo-reservoirs. Numerical approach uses Discrete Element Method (DEM) and the Lower-dimensional Discrete Fracture Model (LDFM) for better understanding spatially-localized and time-varying rock permeability and porosity changes induced by pressurized fluid and gas flow. Tensile and shear micro-cracks may develop in rock mass adjacent to existing fractures with flowing fluid due to the stress re-orientation or localized pressure peaks. As a result, micro-crack damage changes porosity and permeability of the near-fracture zone allows enhanced flow properties, which affects the reservoir large-scale fluid flow dynamics. DEM models micro-scale stress induced damage on a smaller rock element locally subjected to the confining stresses and fluid pressure. DEM uses implicit finite differences for solving stress-strain field in low permeability rock, which is discretized with a system of bonded spherical particles. The fluid flow field uses fluid channels and reservoirs between particles and is fully coupled with the DEM. During the time-stepping procedure, fluid pressure induces stresses on adjacent particles, which displace and open the fluid channels causing the initial permeability increase. In addition, when the fluid pressures exceed tensile or shear bond strength between particles, new micro-cracks occur. Subsequently, the LDFM uses an input function obtained from the DEM model, which relates local porosity and permeability to the fluid pressure in fracture. The LDFM simulates the reservoir-scale gas-water flow through fractured porous media. The two phase flow field is represented with a set of differential equations, which are solved using a fully coupled, fully implicit vertex-centered finite volume method that is known for its robustness and wide range of applicability. Furthermore, the study employs the novel DEM-LDFM coupled approach for investigating the effects of fracturing fluid pressure, gas injection pressure, dynamic viscosity, and fluid and gas compressibility on the evolution of rock damage and rock properties from their initial values due to micro-cracks. Finally, the temporal and spatial change of fracture porosity and permeability as a function of local pressure allows an enhancement of the LDFM fracture parameters and an insight into effects on the large-scale reservoir model.

Introduction

This study quantifies the effect of fracture surface damage caused by secondary processes during CO2 injection on fluid and gas flow and transport in sandstone geo-reservoirs. Numerical approach uses Discrete Element Method (DEM) and the Lower-dimensional Discrete Fracture Model (LDFM) for better understanding spatially-localized and time-varying rock permeability and porosity changes induced by pressurized fluid and gas flow. Tensile and shear micro-cracks may develop in rock mass adjacent to existing fractures with flowing fluid due to the stress re-orientation or localized pressure peaks. As a result, micro-crack damage changes porosity and permeability of the near-fracture zone allows enhanced flow properties, which affects the reservoir large-scale fluid flow dynamics. DEM models micro-scale stress induced damage on a smaller rock element locally subjected to the confining stresses and fluid pressure. DEM uses implicit finite differences for solving stress-strain field in low permeability rock, which is discretized with a system of bonded spherical particles. The fluid flow field uses fluid channels and reservoirs between particles and is fully coupled with the DEM. During the time-stepping procedure, fluid pressure induces stresses on adjacent particles, which displace and open the fluid channels causing the initial permeability increase. In addition, when the fluid pressures exceed tensile or shear bond strength between particles, new micro-cracks occur. Subsequently, the LDFM uses an input function obtained from the DEM model, which relates local porosity and permeability to the fluid pressure in fracture. The LDFM simulates the reservoir-scale gas-water flow through fractured porous media. The two phase flow field is represented with a set of differential equations, which are solved using a fully coupled, fully implicit vertex-centered finite volume method that is known for its robustness and wide range of applicability. Furthermore, the study employs the novel DEM-LDFM coupled approach for investigating the effects of fracturing fluid pressure, gas injection pressure, dynamic viscosity, and fluid and gas compressibility on the evolution of rock damage and rock properties from their initial values due to micro-cracks. Finally, the temporal and spatial change of fracture porosity and permeability as a function of local pressure allows an enhancement of the LDFM fracture parameters and an insight into effects on the large-scale reservoir model.

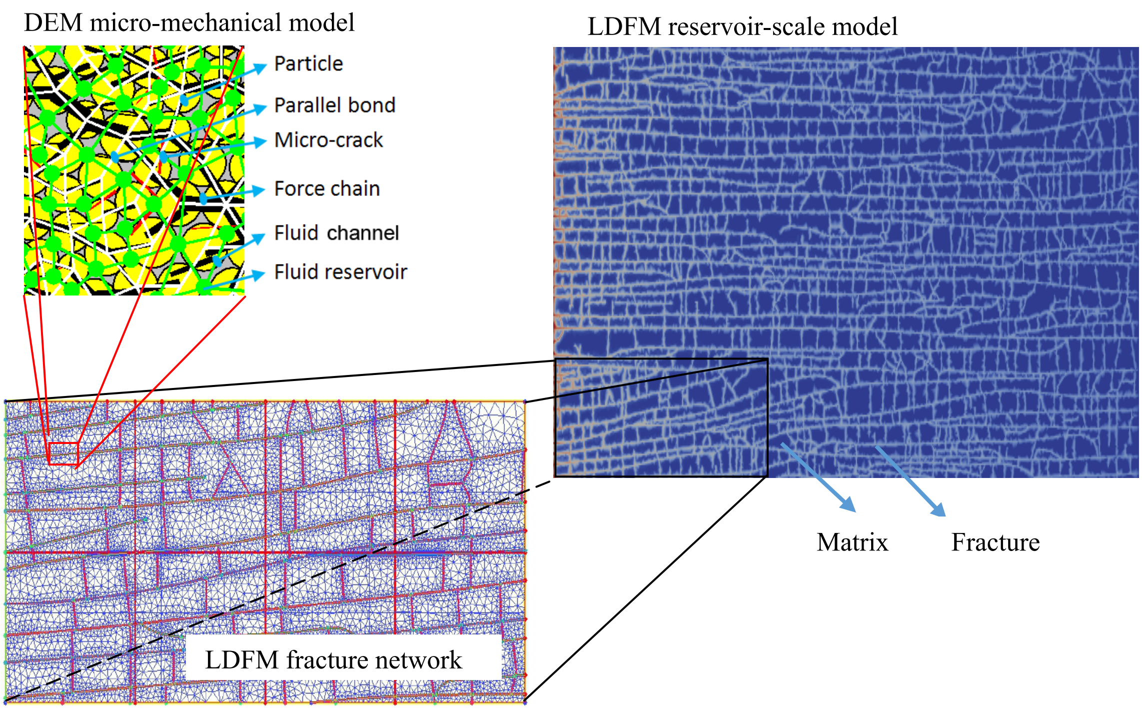

Figure 1 *Illustration of the coupling scheme between the Discrete Element Model (DEM) and the Lower-dimensional Discrete Fracture Model (LDFM).*