Experimental Investigations of Fractured Rock Permeability Hysteresis

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INTRODUCTION
- Hysteretic behavior of fractured rock permeability is noticed in core flood experiments, due to the uneven surfaces of fractures.
- Permeability is measured using a high pressure core flood apparatus with X-Ray Computer Tomography (CT) scanning to measure the fracture aperture.
- Clear hysteretic behavior is observed in both permeability and fracture aperture in repeated cycles of compression and decompression.
- Higher maximum pressure corresponds to lower permeability cycle.
- The reasons for this hysteretic behavior, based on our investigation, are mainly surface asperity deformation and friction between asperities.

DARCY’S LAW
Permeability is one of the most important parameters in Darcy’s Law:

\[ q = -\frac{\mu \Delta P}{\kappa} \]

where:
- \( q \) is the flux (discharge per unit area, with units of length per time, m/s),
- \( \mu \) is permeability (m²),
- \( \Delta P \) is the pressure difference (Pa),
- \( \mu \) is the phase viscosity (water/oil/gas) (Pa·s).

EXPERIMENT SETUP
- Core flood experiment.
- CT scanning.
- A high permeability core (500mD) sliced into half using saw.

EXPERIMENT RESULTS
- Clear hysteretic behavior in permeability measurement in repeated cycles of compression and decompression.
- Higher maximum pressure corresponds to lower permeability cycle.

FRACTURE SURFACE DEFORMATION/FRICTION
- Scanning Electron Microscope images of original fracture surface and the fracture surface after withstanding effective pressure of 6000psi.
- Before and after images show changes in the fracture surface.

CONCLUSIONS AND FUTURE WORK
- The large hysteresis indicates the irreversible deformation of fracture asperities.
- A certain fraction of asperities will deform under different pressures exerted to the rock fracture surfaces, which results in different hysteresis loops accordingly.
- At fixed effective pressure, friction causes the difference between compressing line and decompressing line at fixed maximum effective pressure.
- Experiment work on fracture relative permeability behavior and simulation work with fracture permeability hysteresis.

REFERENCES
1. Kassis and Sondergeld, 2010
2. Pini et al., 2012

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