Core Flooding Experiments Combined with X-Ray CT & Micro-PET Imaging as a Tool to Calculate Fluid Saturations in a Fracture

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Context
Multiphase flow through fractured porous media is relevant because fractures can be the dominant flow paths in a wide range of environments.

Motivation
It is known that fracture relative permeabilities are not linear functions of saturation, but still, this assumption is commonly used in numerical simulations.

Goal
To measure the degree of saturation in the fracture, providing the relative permeabilities curves for the numerical simulations and to describe the different phase flows behavior in a fracture.

Experimental Procedure

Core-flooding
First N₂ and then water are injected at different flow rates while the pressure drop along the core is measured.
Afterwards, a drainage process is forced by co-injecting N₂ and water and increasing the gas ratio stepwise while fixing the total volumetric flow rate.

X-Ray CT Imaging
The intensity of a collimated X-Ray beam passing through the core is measured by detectors located opposite the X-Ray source.
The fracture aperture map is obtained by using a calibration free missing CT attenuation method (Huo et al. 2016).

PET Imaging
Relies on the production of emitting radionuclides that are detected with an array of photon detectors that surround the core.
Water with tracer, Fluorine radioisotope, is injected to spot water flux in the fracture.

Conclusions
CT images provide structural data while PET allows us to see how fluids flow through the fracture.
The combination of core flooding experiments and CT scan imaging allows us to calculate not only the mean fracture aperture but the distribution of the apertures through the fracture.
Adding PET scan imaging is the key to be able to calculate the water saturation in the fracture.

References
Huo, D., Pinni, R. and Benson, S., 2016. A calibration-free approach for measuring fracture aperture distributions using X-ray computed tomography, Geosphere v.12, n02, doi: 10.1130/GEOS1175.1

Experimental set up
Back P=300 psi
Confining P=600 psi
T= 50 °C

(Figure modified from Huo & Benson 2016)

Darcy’s law is used to calculate permeability and relative permeability.

Multiflange flow shifts quickly from being dominated by one phase to another phase, implying that both phases are very interfering. It is hard for the gas to displace the water and gas relative permeability is close to zero until gas fraction reaches the 90%.

References

Gas flow does not displace completely the water inside the fracture.
Multiphase flow shifts quickly from liquid to gas dominated system.