Deformable porous media saturated by three immiscible fluids: Constitutive modeling and core flooding simulations

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INTRODUCTION

- The coexistence of three non-miscible fluids, typically water, a gaseous and an oily phase, is typical of (e.g.)
  - soil decontamination, such as air sparging techniques
  - enhanced hydrocarbon recovery (EOR) processes, such as gas or steam injection and water-alternating-gas (WAG) injection.
- In such cases, three fluid phase modelling is required.
- A comprehensive framework based on the finite element method to simulate fluid injection/imbibition processes in deformable rocks saturated by three immiscible fluids is developed, without resorting to specific simplifications.
- The proposed model is then used to simulate different types of core flooding experiments.

MODEL FORMULATION

Capillary pressures for a three-fluid phase porous medium

\begin{equation}
\begin{align*}
P_{\text{cmw}} &= p_{\text{cmw}} \cdot p_{\text{w}} \\
P_{\text{cmg}} &= p_{\text{cmg}} \cdot p_{\text{g}} \\
P_{\text{cmw}} &= p_{\text{cmw}} \cdot p_{\text{w}} + p_{\text{cmg}} \cdot p_{\text{g}}
\end{align*}
\end{equation}

Original relations are proposed, to provide more realistic curves over the irreducible saturation triangle

GAS INJECTION USING BROOKS-COREY TYPE PERMEABILITY MODEL

- Relative permeability contours to water, oil and gas over the saturation domain.
- Schematic of coreflooding gas injection simulation.
- Relative permeability contours to water, oil and gas over the saturation domain.
- Schematic of groundwater pollution with hydrocarbons, that may be treated with (e.g.) air sparging.

GAS INJECTION USING ALTERNATIVE PERMEABILITY MODELS

- Relative permeabilities to water, oil and gas over the saturation domain represented both in 2D and 3D using the bundle model.
- Schematic of Water-Alternated-Gas injection. Image from statoil.com
- Schematic of Water-Alternated-Gas injection simulation using the bundle model.
- Gas saturation spatial profiles during gas injection simulation using the bundle model.
- Water saturation spatial profiles during gas injection simulation.
- Oil saturation spatial profiles during gas injection simulation.

WAG INJECTION USING BROOKS-COREY TYPE PERMEABILITY MODEL

- Schematic of groundwater pollution with hydrocarbons, that may be treated with (e.g.) air sparging. Image from wrd.org
- Gas saturation spatial profiles during water-alternating-gas simulation (water injection phase).
- Oil saturation spatial profiles during water-alternating-gas simulation (water injection phase).
- Water saturation spatial profiles during water-alternating-gas simulation (water injection phase).
- Schematic of Water-Alternated-Gas injection simulation using the bundle model.
- Schematic of Water-Alternated-Gas injection simulation using the bundle model.

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References:
