Multiphase flow model of Naturally Fractured Reservoirs using EDFM

*Paper prototype*

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# Motivation and Vision

We want to enable EDFM technology to represent Naturally Fractured Reservoirs (NFRs).

Recent EDFM papers focus mainly on hydraulic fracture models, where the pressure gradient between the fracture and its surrounding matrix dominates the flow, and single-phase models are accurate.

When we consider natural fractures occurring far from the wells, capillarity dominates the flow dynamics, because the local pressure gradient is small.

# Hypotesis

EDFM must be enhanced to model capillary driven flow in NFRs.

Wettability and buoyancy are the key parameters that control the flow dynamics in conventional and thick NFR.

# Workflow

1. **Preliminary simulation work:** Demonstrate the issue with preliminary simulation work.
2. **Multiphase model:** Offer a numerical approach to solve the issues identified
3. **Benchmark the model:** test against and models, estimate recovery factors in waterflooding and gasflooding scenarios.

# Preliminary simulation work

## PETROPHYSICS AND FLUID PROPERTIES

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| Model | Black oil |
| RGO |  |
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## RESERVOIR GEOMETRIES

### F1: Multiple fractures

Build a reference model able to stress the multiphase flow in the absence of a areal pressure gradient. This is a 2D model with a regular fracture network initially saturated with water. Two fluid equilibrium regions: one for the matrix and one for the fracture. Let the flow equilibrate naturally and measure the characteristic times.

The model can be implemented using , EDFM and LGR.

|  |  |
| --- | --- |
| (model height) |  |
| (model width) | 10 |
| Frac Spacing |  |

A screenshot of a game

Description automatically generated

Figure 1 – Reservoir geometry F1.

## CAPILLARY PRESSURE

Elaboborate reference cases.Observe that the fracture has low but not null .

TBD – pair of curves: one for the matrix and one for the fracture, for each scenario:

### PCWO-WW: Water-oil capillary pressure, strongly water wet media

### PCWO-MW: Water-oil capillary pressure, mixed wet media

### PCWO-OW: Water-oil capillary pressure, strongly oil wet media

### PCGL-WW: Gas-liquid capillary pressure

Use a unique gas-liquid capillary pressure, regardless of wettability.

## RELATIVE PERMEABILITY

TBD – pair of curves: one for the matrix and one for the fracture, for each scenario:

Elaboborate reference cases for fracture and matrix.

### KRWO-WW: Water-oil relative permebility, strongly water wet media

### KRWO-MW: Water-oil relative permebility, mixed wet media

### KRWO-OW: Water-oil relative permebility, strongly oil wet media

* Objective function: OIL RECOVERY;
* Contributions:
  + VALIDATION and COMPARISON of , and EDFM capabilities to represent the OIL RECOVERY MECHANISMS and CHARACTERISTIC TIMES in a natural fracture model.
  + GUIDELINES and CRITERIA for TECHNOLOGY SELECTION in representing of Waterflooding and Gasfooding as EOR in Naturally Fracture Reservoirs.
* Assumption for VALIDATION
  + Regular small-scale model
  + Use a LGR model as reference
  + Derive , and shape functions to use for comparison
* Assumptions for COMPARISON
  + homogenous matrix and fracture;
  + single geological scenario of fractures;
  + model scale suitable for phenomenological investigation;
  + injection and production rates suitable for the model scale.
* Main motivation/hypothesis:
  + whereas the offers some flexibility in the shape function formulation to represent multiphase flow and gravity effect on the matrix-fracture exchange, the capability of EDFM using non-neighboring connections to come up with the same level of representation is not fully proved;
  + Methodological guidelines for multiphase flow using EDFM approach.
* Literature survey:
  + Panorama on EOR methods in NFR
  + Recovery mechanisms in naturally fractured media;
  + Physical phenomena
  + effective models
  + multiphase flow characterization;
  + EDFM multiphase characterization and gaps
* Methodology
  + Build an explicit discrete fracture reference model we can trust, and that can represent all phenomena.
  + Build Gilman-Kazemi and EDFM models
  + Measure the transfer rate between fracture and matrix and compare the methods transients
  + Measure characteristic times
  + Measure oil recovery
* Two independent systems:
* water and oil – waterflooding as a recovery method;
* oil and gas – gasflooding as a recovery method.

Sensitivity parameters:

|  |  |
| --- | --- |
| **Property** | **Related phenomenon** |
| Compressibility | Compressibility's role in the fluid recovery |
| Buoyancy (thickness, fluid density contrast) | Gravitational segregation and convection within the fractures |
| Capillarity and relative permeabilities | Matrix-fracture transfer and wettability dependence. Strong interplay with gravity. |
| Contrast between matrix and fracture permeabilities | Viscous-driven displacement |
| Fluid velocity (Forchheimer’s parameter) | Non-Darcy effect on the injectivity and productivity (for gas-oil system) |
| Diffusion coefficient | Diffusion mechanisms for multi-component gas-oil systems (it should be excluded if our investigation is restricted to a black-oil model). |

# Collection of citations

(Moinfar et al., 2014; Xu et al., 2017) – original EDFM

(Gilman & Kazemi, 1983; Horie et al., 1990) – Original investigation of multiphase flow in NFR

(Karimi-Fard et al., 2004) – example of the multiphase flow issue in NFR

(Wu, 2015) – Book that points issues on multiphase flow and fractures

(Wong et al., 2020) – Paper from Heriot Watt (Seb. Geiger), offers a framework for NFR characterization from explicit models. This paper is very close to our idea. Uses EDFM and hybrid models. Discusses the driving forces. PROBLEM: his KREL and PC are not consistent with the Water-gas system and wettability is not discussed. Important comment: “However, to our knowledge, no such validation has been performed for more complex flow phenomena that involves capillarity and gravity. Nevertheless, EDFM has been used in many studies …”.

(Lu et al., 2008) – paper from Martin Blunt explores transfer functions for multiphase flow. Suggests we can have a transient transfer function for matrix to fracture instead of multiple fracture blocks. Interesting method to compare the flow rates between matrix and fracture.

(March et al., 2016) – Shape functions to account for early times (normally shape functions take care only of pseudo-steady-state)

(Bourbiaux, 2010) – overview of NFR simulation, panorama and method to choose between SP, DP and DPDK

# References

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