Status of simulation software in OPM

Tor Harald Sandve

OPM meeting, Trondheim, 11 March
Overview of simulators

› **FLOW (Fully implicit black-oil simulator)**
  • Polymer flooding
  • Thermal simulations

› Ewoms

› Single-phase and steady state upscaling

› PORSOL (IMPES black-oil simulator)

› Multiple solvers for 2-phase flow

› Vertical equilibrium simulator (2-phase flow)
FLOW (Fully implicit black-oil simulator)

› Based on automatic differensialization
› IO
  • Read Eclipse decks
  • Output Eclipse summary, restart and egrid files
› Grid
  • Corner point geometry with faults
  • Modification of transmissibilities
    – Region multipliers
    – Fault multipliers
  • Net-to-gross
  • MINPV / PINCH
› Initialization
  • Equilibrium
  • Initial water saturation
› Properties
  • Dissolved gas
  • Vaporized oil
  • Capillary pressure
  • End-point scaling
  • Hysteresis (using end-point scaling)
  • Oil vaporization controls (VAPPARS)
› Wells
  • Control: BHP, surface rates and reservoir rates, (Group)
  • Shutting/Stopping/Opening wells and individual completions
  • History matching wells
› CPR preconditioner
› Time-step controls
Comparison SPE 9

› 9000 cells
› high degree of heterogeneity in the permeability field.
› 25 producers and one injector. Well controls changed several times during simulation.
Oil production

[Graph showing oil production over time with two lines labeled 'OPM' and 'Industry standard simulator']
Water production

![Water production graph](image_url)
Comparison Norne

› 44431 active cells
› 10 years of historical injection and production rates
› 8 injectors and 28 producers
› End-point scaling
› Hysteresis
Norne results: Production wells

BHP  Oil  Gas  Water

B-1H

B-2H

B-3H
Norne results: Producing wells

BHP

Oil

Gas

Water

B-4H

D-1H

D-2H

12 March 2015
Norne results: Producing wells

D-4H

E-1H

E-2H

BHP

Oil

Gas

Water
Norne results: Injecting wells

C-1H

BHP

Gas

Water

C-2H

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Norne results: Injecting wells

BHP

Gas

Water

C-3H

F-1H

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## Performance SPE1 and SPE9

<table>
<thead>
<tr>
<th></th>
<th>Eclipse OPM (BiCG + iLU + tuning)</th>
<th>SPE 1</th>
<th>SPE 9</th>
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<td><strong>Total time (sec.)</strong></td>
<td></td>
<td>0.4</td>
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<td>OPM (Gmres + iLU)</td>
<td>1.65 (4.1)</td>
<td>39.2 (11.9)</td>
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<td>3.19 (7.9)</td>
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<td><strong>Total Newtons</strong></td>
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## Performance Norne

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<th>OPM (BiCG + fastAMG + tuning)</th>
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FLOW-Polymer

› Compressible oil-water-polymer solver
› Black-oil-polymer solver
› (Also a sequential version)
FLOW-Thermal

- Temperature dependent properties
  \( x(p,T) = x_p(p) * x_T(T) \)
- Iso-thermal
- TODO: Solve energy equation
eWoms

eWoms not a simulator, but a framework to easily create one:

› Fully implicit solvers:
  • Element centered finite volume method
  • Vertex centered finite volume method
  • Implicit Euler for time discretization

› Currently featuring 7 porous media flow models, including
  • Richards
  • Immiscible fluids
  • Black-oil
  • Three fully compositional models

› Support for MPI and OpenMP (thread) parallelism

› Uses linear solvers of Dune-ISTL

› Support for the ECL decks via 'ebos' simulator
  • Same results as 'flow' and Eclipse 100 for SPE1 and SPE9
  • Some more advanced features not yet implementet

› Support for arbitrary number of fluid phases in all "generic" model

› Optional energy conservation for most model

› All models switchable between Darcy and Forchheimer velocities
Upscaling

› **Permeability (single-phase)**
  - Flow-based: solve directional pressure problems
  - Much more accurate than harmonic averaging etc.
  - Mimetic discretization of pressure
  - Linear solver: dune-istl AMG (or FastAMG)
  - Fixed, Linear or Periodic boundaries
  - Produces symmetric tensor (with periodic boundaries)

› **Relative permeability (two-phase)**
  - Compute a steady-state for given configuration
  - Depends on flow direction, pressure drop, initial saturation
  - Compute upscaled perm based on phase mobilities
  - Produces full tensor relperm as output
  - Computing steady states
    - Two-phase incompressible, immiscible flow
    - Include capillary pressure, gravity
    - Fixed, Linear or Periodic boundaries
    - Pressure: mimetic discretization, AMG
    - Saturation: TPFA discretization, explicit or implicit Euler
Next steps (for the FLOW simulator)

› Energy equation
› Extended black-oil model (3 phase, 4 component) for CO2-EOR simulations
› Continue adding features to support new fields.
› Parallelization
› Refactoring
› Performance
› Release