EVALUATION OF WELL SPACING AND ARRANGEMENT FOR IN-SITU THERMAL TREATMENT OF OIL SHALE USING HPC SIMULATION TOOLS

MICHAL HRADISKY - JENNIFER SPINTI - PHILIP J. SMITH
INSTITUTE FOR CLEAN AND SECURE ENERGY - UNIVERSITY OF UTAH

34TH OIL SHALE SYMPOSIUM
COLORADO SCHOOL OF MINES, GOLDEN, CO
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OVERVIEW

Oil Shale/Oil Sands program

Simulation tool / HPC

Co-Simulation

Well spacing study

What’s next ...
OIL SHALE / OIL SANDS PROGRAM

Mission: Pursue research that improves industry’s ability to utilize the vast energy stored in oil shale and oil sands resources with minimal environmental impact

Three main research areas:
1. Basin scale simulation of environmental and economic impacts of oil shale and oil sands development
2. Secure liquid fuel production by in-situ thermal processing of oil shale and oil sands
3. Environmental, legal, economic and policy issues
OIL SHALE / OIL SANDS PROGRAM

Research topics such as:

- Multiscale thermal processes
- Reservoir simulations
- In-situ pore physics
- Experimental characterization of oil shales and kerogens
- Geomechanical reservoir state
- Developing a predictive geologic model of the Green River oil shale in Uinta Basin
- Development of HPC simulation tools

CAPSTONE PROJECT
Collaborated with American Shale Oil LLC to further develop simulation tools on a realistic problem.
STAR-CCM+

Commercially-available engineering process tool for solving problems involving flow, heat transfer, and stress developed by CD-adapco

Designed for problems involving multi-physics and complex geometries

Build-in 3D CAD package to create complex geometry and interface with external commercial CAD packages

Supports parallelism

Supports user code for expanded applicability
CO-SIMULATION

Capability added during Capstone project

Addresses the need to capture and couple small convective scales with larger conductive scales

Used data shared by AMSO to simulate certain aspects of their pilot tests

Last year: Two separate simulations
  1. Resolve refluxing throughout the heater well
  2. Perform conduction-only study to capture thermal diffusion throughout the formation

This year: Coupled both simulation
Heater in the lower lateral well

Side View of Simulation Domain
CO-SIMULATION

SOLID

TIME SCALES:
~ DAYS

SPATIAL SCALES:
~ 1 M

FLUID

TIME SCALES:
~ SECONDS

SPATIAL SCALES:
~ 1 CM
Fluid
LES: 17 mil cells

Solid
Conduction only: 2.4 mil cells

720 cores 480 cores

120 m
30 m
75 m

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HEATER TEST RESULTS ~ 3 MONTHS

NO CO-SIMULATION

Side View

Top

Bottom
HEATER TEST RESULTS ~ 3 MONTHS WITH CO-SIMULATION

Side View

Top

Bottom
STUDY AREA - UINTA BASIN

“WHAT IF” SCENARIO
STUDY AREA - UINTA BASIN

“WHAT IF” SCENARIO
STUDY AREA - UINTA BASIN

“WHAT IF” SCENARIO

Michael D. Vanden Berg, UGS
Lauren P. Birgenheier, U of U

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STUDY DOMAIN

250 m

450 m

125 m

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BOUNDARY CONDITIONS

Periodic boundaries

Results can be scaled up

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STUDY SCENARIOS

Case 1: 25 m lateral well spacing (5 wells)
STUDY SCENARIOS

Case 1: 25 m lateral well spacing (5 wells)

Heated pipe length 300 m
STUDY SCENARIOS

Case 2: 12.5 m lateral well spacing (10 wells)
Case 3: 12.5 m lateral well spacing, every other well is offset vertically 12.5 m (10 wells)
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SIMULATION SETTINGS

Conduction only

No collector well inside the geometry

What is produced is what is collected

Constant heating temperature 675K for the entire length of the horizontal well

Diameter of horizontal well: 0.5m

Oil shale kinetics based on sample from Uinta Basin (Dr. Tom Fletcher, BYU)

\[ A = 9.5 \times 10^{13} \text{ J/s} \quad E = 221 \text{ kJ/mol} \]
Total cell count ~50 mil
SIMULATION MESH

Total cell count ~50 mil

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SIMULATION MESH

Total cell count $\sim 50$ mil
Oil shale grade (GOPT)
SIMULATION PROPERTIES

Density (kg/m$^3$)
RESULTS: CASE 1

Time (days): 0.25
RESULTS: CASE 2

Time (days): 0.25

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RESULTS: CASE 3

Temperature (K)

<p>| | | | |</p>
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>300.0</td>
<td>375.0</td>
<td>450.0</td>
<td>525.0</td>
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</table>

Time (days): 0.25
RESULTS: CASE 3

Time (days): 0.25
PRODUCT YIELD

# of Days

- CASE 1
- CASE 2
- CASE 3

Oil yield (cubic m)

1 91 181 271 361 451 541 631 721
### Energy Ratio - 2 Yrs Heating

<table>
<thead>
<tr>
<th>Case</th>
<th>Energy In (x10)</th>
<th>Oil Yield (m)</th>
<th>Oil equivalent Energy Out (x10)</th>
<th>NG equivalent Energy Out (x10)</th>
<th>Energy In/Energy Out</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>13.9</td>
<td>592</td>
<td>6.33</td>
<td>6.84</td>
<td>2.03 - 2.20</td>
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<tr>
<td>Case 2</td>
<td>27.3</td>
<td>1,175</td>
<td>12.6</td>
<td>13.6</td>
<td>2.00 - 2.17</td>
</tr>
<tr>
<td>Case 3</td>
<td>43.2</td>
<td>1,120</td>
<td>12.0</td>
<td>12.9</td>
<td>3.35 - 3.60</td>
</tr>
</tbody>
</table>
CONCLUSIONS

Used simulations to look at “what if” scenarios located in the Uinta Basin

For conductive heat transfer retorting
1. Required power input exceeds energy content of product
2. Majority of heat is used to heat distant surrounding rock to low temperatures

Using simulations can evaluate strategies to increase product yield
1. Drill additional wells to provide more heat
2. Increase temperature in the heating well
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Need to introduce convective heat transfer to increase the rate of heating

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CONCLUSIONS

HPC simulations can provide high fidelity over long time periods
1. Can resolve localized heat transfer
2. Comes at a cost
   - approx. 150,000 CPU-hr per computation
   - ~520 days on 12-core workstation

- The rate-limiting step is the rate of heat transfer during thermal treatment process
  - Need to get the heat transfer right
- Developing CFD-based simulation tool
  - Using CFD-based tools on a reservoir scale
  - Offers potential for future enhancements to capture important physics in a realistic domain
  - Offers better strategy for designing/evaluating technologies
- Help to maximize economic return and minimize risk

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WHAT’S NEXT ...

40 m

40 m

125 m
WHAT’S NEXT ...
WHAT’S NEXT ...
WHAT'S NEXT ...
ACKNOWLEDGEMENTS

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