AN OVERVIEW OF HEAVY OIL RECOVERY STUDIES
AT THE CENTRE FOR ENHANCED OIL RECOVERY AND CO2 SOLUTIONS OF
HERIOT-WATT UNIVERSITY

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Outline

- Introduction & Objectives
- Experimental Facilities
- Visualization Experiments
- Coreflood Experiments
- Conclusions
Heavy Oil Recovery

- Very low primary production (5% to 10%) and poor waterflood performance.

- Thermal methods are applied in the field but there are limitations:
  - thin and deeper reservoirs
  - energy intensive
  - environmental issues e.g. carbon footprint

- Non-thermal recovery methods provide a solution for reservoirs in which thermal methods are impractical or uneconomical also offer advantages on capital cost, energy consumption, environmental pollution etc.
The objective of the Non-Thermal Enhanced Oil Recovery JIP at Heriot-Watt is to investigate potential of improving heavy oil recovery by:

- Water/CO2 combinations  (focus of this presentation)
- Chemical Injection, and
- Mobility control techniques.
Mechanisms of Oil Recovery by CO2 Injection

- Interactions of CO2 and crude oil are different in heavy oil compared to conventional oil

Light Oil Systems

Heavy Oil Systems

Klins, 1984
While miscibility would be absent, large drops in heavy oil viscosity takes place upon mixing with CO2.
Our research approach:

- Investigate pore-scale physics by performing visualization experiments
- Quantify level of additional oil recovery by each method by core flood experiments under reservoir conditions.
- Performed simulation and modelling at core and field scales.
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Eight heavy crude oil samples were provided by sponsor companies from reservoirs around the world. The viscosity range was from 5 to 10000 cp at their test conditions. The focus of this presentation is on the following two heavy oils.

<table>
<thead>
<tr>
<th>Crude</th>
<th>API°</th>
<th>Viscosity (cp)</th>
<th>Pressure (psig)</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>“C”</td>
<td>10</td>
<td>8700</td>
<td>600</td>
<td>50</td>
</tr>
<tr>
<td>“J”</td>
<td>16</td>
<td>617</td>
<td>1500</td>
<td>28</td>
</tr>
</tbody>
</table>

Experimental Work

- **Fluid Characterization**: Viscosity, composition, Wettability, IFT, Acid number, etc.
- **Flow Visualization Experiments**: Using the transparent micromodels to investigate the displacement mechanisms at the pore scale,
- **Displacement Experiments**: Using Sandpack and consolidated cores to up-scale and quantify the observations in the micromodel.
High-pressure micromodels allow detailed investigation of pore-scale mechanisms under reservoir conditions.
Coreflood Rig
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Low Pressure (gaseous) Application of CO2 (Crude C)

Initial Waterflood Flood – poor oil recovery

CO2 Flood at CO2 Breakthrough

CO2 Flood after 2 days – note change of colour of oil due to dilution with CO2

Water injection after CO2 flood resulted in significant additional oil recovery
High Pressure (Super Critical) Application of CO2 (crude J)
Mobility Control by CO2-Foam (Crude C)

Initial Oil Saturation

Surfactant Flood

CO2-Foam, 1 hr

CO2-Foam, 2 hrs

CO2-Foam, 5 hrs

CO2-Foam, 1 day
Oil Recovery Comparison (Crude C)

- CO2 Flood after 2 days
- CO2 and Water injection (slugs)
- CO2-Foam injection 1 day
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Oil Recovery by Waterflood (Heavy Oil vs. Light Oil)

- Heavy Oil - 617 cp
- Light Oil - 1 cp

Graph showing oil recovery (% OOIP) vs. injection brine (PV).
Heavy Oil Recovery by CO2 Injection (Tertiary Vs Secondary)

Crude J – 617 cp (medium heavy oil)
Mobility Control by CO2-Foam (CO2 inj Vs CO2Foam)

Crude C – 8670 cp (extra heavy oil)
While in conventional oil reservoirs the amount of CO2 that can be stored in water flooded reservoirs (tertiary) is much lower than secondary. In heavy oil systems, CO2 storage capacity is almost the same for secondary and tertiary CO2 injection.
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Conclusions

- The results of this study show significant potential for enhanced oil recovery and CO2 storage in heavy oil reservoirs.

- The coreflood results show that the performance of CO2 is, to a large extent, dependent on reservoir conditions, the state of CO2 under reservoir conditions, and physical properties of the heavy crude oil.
Conclusions

- Comparison of recovery data during secondary and tertiary injection of CO2 reveals that secondary CO2 injection provides much better recovery efficiency at early injection times.

- While CO2 storage capacity in light oil systems is a strong function of injection mode (pre- or post-waterflood), heavy oil systems show much less sensitivity to CO2 injection strategy.
Conclusions

- The results of micromodel and coreflood experiments revealed that when the CO2 flood process is boosted by an appropriate mobility control technique (e.g. in-situ formation of foam), heavy oil displacement process takes place in a much shorter time period and more efficiently.
Acknowledgment

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