IPTC-17456-MS
Chemical Consolidation of Sand Propped Fractures in a Chalk Reservoir Offshore Denmark With Enzymatic Calcium Carbonate Scale

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Safety Moment

The facility was not designed for proppant/sand production
Danish Sector - North Sea

- Chalk
  - Low permeability (1-10 mD)
- Long horizontals
- Stimulation
  - Fracture (acid or proppant)
  - Matrix acidize
- Wells from 1980’s:
  - Propped Fractures destabilize
Problem well

- Good oil producer
- Completed 1993
- 8 Propped fractures
  - Total 6 millions pounds
- Choked back – sand production
- CT intervention July 2012
  - Eroded holes in tubing
  - 90% of oil through holes

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How to stop sand (and not the oil)?

Options considered:

- Insert screens
- Resins
- Enzymatic calcium carbonate

Benefits:
- Environmentally friendly
- Completely reversible
- Life Cycle Solution

Reference Paper: SPE#144047

Once the solution was selected lab testing was done in parallel with planning of job.
Enzymatic Calcium Carbonate Scale – The Reaction

1) $\text{Urea} + \text{Water} \rightarrow \text{Ammonia} + \text{Bicarbonate}$

$$\text{NH}_2\text{-CO-NH}_2 + 2\text{H}_2\text{O} \rightarrow 2\text{NH}_4^+ \text{(aq)} + \text{CO}_3^{2-} \text{(aq)}$$

2) Calcium Solution + Bicarbonate → Calcium Carbonate

$$\text{Ca}^{2+} \text{(aq)} + \text{CO}_3^{2-} \text{(aq)} \rightarrow \text{CaCO}_3(\text{s})$$
Laboratory Testing - Injection

- Unconsolidated Proppant
- Treatment
- Permeability Assessment

<table>
<thead>
<tr>
<th>Coreflood</th>
<th>Pre-Treatment permeability (mD)</th>
<th>Post-Treatment permeability (mD)</th>
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<tr>
<td></td>
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<td>After Injection 1</td>
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<tr>
<td>#1 (3 injections)</td>
<td>11337</td>
<td>8543 (75%)</td>
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<tr>
<td>#2 (2 injections)</td>
<td>11070</td>
<td>9315 (84%)</td>
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Laboratory Testing – Flow Back

Post-treatment sand production testing verified improved strength
Job Preparation

- Chemical Contamination
- Chemical Decomposition
- Downhole Temperature
- CaCO$_3$ Precipitation inside the CT
- Logistically Challenging
- CT on Paper
Case Study Offshore Field Application – Job Execution

- Zonal Isolation treatment packers
- Downhole memory gauges to monitor & optimize job
- Formation Cooling

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Case Study Offshore Field Application – Job Execution

- Pumping of treatment
- Wait for consolidation
- Repeat 3 times
- Recover Packers
Case Study Offshore Field Application – Well Clean Up

• Solids Sampling & Removal
• Accoustic Sand Detection
• Monitor Production Rates
Case Study Offshore Field Application – Results

- 700 BOPD sand free production at a gross rate 4200 BLPD
- 7 Months after intervention well producing 800 BOPD
- Payback achieved under 100 days
- Limited productivity impact

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<th>Zone 7</th>
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Conclusions

- Environmentally friendly solution for remedial downhole sand consolidation.
- Restored over 700 BOPD of sand free production
- Attention to detail is imperative and can impact the effectiveness of the chemical treatment.
- Above expectation performance ~151,000 STB in first 7 months
Questions