Application of Intelligent Chemical Tracers in a Horizontal Open Hole Multistage Fractured Well for Downhole Performance Monitoring

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Outline

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  • Design Parameters
  • Tracers System
• Sampling Program
• Interpretation
• Lessons Learnt and Conclusions
Objectives

Multistage hydraulic fracturing techniques in horizontal open hole wells is becoming more and more common completion practice for developing tight sandstone reservoirs.

Downhole performance monitoring is a key factor for:

• understanding the effectiveness of fracturing treatments and their relative clean-up
• evaluating the inflow zonal contribution
• identifying water breakthrough location
• optimizing any kind of future well intervention
Three hydraulic fracturing stages have been carried out and Chemical Inflow Tracers have been used to identify oil and water production from each different fractured interval. Polymer rods, embedded with uniquely identifiable oil and water chemical tracer, have been placed immediately above and below each frac port.

High differential pressure open hole packers have been used to compartmentalize the horizontal section.

Upon well start-up liquid samples have been obtained at the surface and analyzed for tracer content. The responses have been interpreted to identify which zones were effectively contributing to production.
Well Data

Intelligent Chemical Inflow Tracers have been successfully applied on well Foukanda Marine 103-st, located in off-shore Congo.
Well Data

FOKM 103-st

Water depth  105.0 m
Air gap  30.7 m
Final depth  3185.0 m MD
  1633.7 m TVD
Max inclination  87°
Design Parameters

3 OIL and 3 WATER tracer systems delivered

- Oil density: 34° API
- Reservoir temperature: 65°C = 149°F
- Reservoir pressure: 130/160 bar = 1885/2320 psi
- Reservoir permeability: 15 mD
- Expected total flow rate: 1500 bpd
- Maximum water rate: 750 bpd (50%WC) during clean-up
  100 bpd (7%WC) during steady state production
- Marking period: 3 years (oil) – 1 year (water)
Lower Completion

- Open hole size: 6”
- Open hole length: 563.0 m
- Tubing: 4 ½” 12.6# L80 VAGT
- Multistage frac system
- RESMAN inflow tracer system
Tracer Carrier System

5.24" i-Trac (4.5" Base pipe)

2 sections

Base pipe
4 ½” 12.6# L80
LTC box x pin

Base pipe length
3.5 m

Data sheet:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>OD</td>
<td>133mm / 5.24&quot;</td>
</tr>
<tr>
<td>Length of shroud</td>
<td>2505mm / 98.6&quot;</td>
</tr>
<tr>
<td>Strength properties</td>
<td>100% of pipe</td>
</tr>
<tr>
<td>Tracer rod</td>
<td>(3.5 x 8.5) 1.1 m x 32 x 2 [70m] of tracer</td>
</tr>
<tr>
<td>Total ventilation:</td>
<td>4.000 mm²</td>
</tr>
</tbody>
</table>

Ventilation on slip cone
2 x 16 x 8mm holes → 1.600 mm²

Ventilation on shroud
2 x 24 x 8mm holes → 2.400 mm²
Sampling Program

• Sampling program during clean-up phase

<table>
<thead>
<tr>
<th>Time interval</th>
<th>Cumulative hours after well start-up</th>
<th>Sampling frequency (one sample every)</th>
<th>Number of samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 hour</td>
<td>0 – 1 hours</td>
<td>15 minutes</td>
<td>4</td>
</tr>
<tr>
<td>3 hours</td>
<td>1 – 4 hours</td>
<td>5 minutes</td>
<td>36</td>
</tr>
<tr>
<td>2 hours</td>
<td>4 – 6 hours</td>
<td>10 minutes</td>
<td>12</td>
</tr>
<tr>
<td>2 hours</td>
<td>6 – 8 hours</td>
<td>15 minutes</td>
<td>8</td>
</tr>
<tr>
<td>4 hours</td>
<td>8 – 12 hours</td>
<td>30 minutes</td>
<td>8</td>
</tr>
<tr>
<td>? hours</td>
<td>12 – until end of clean-up</td>
<td>60 minutes</td>
<td>~12</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Total number of samples</strong></td>
<td>~80</td>
</tr>
</tbody>
</table>

• Sampling program during production phase

<table>
<thead>
<tr>
<th>Time interval</th>
<th>Sampling frequency (one sample every)</th>
<th>Number of samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stable production</td>
<td>One duplet of samples taken every week during stable production</td>
<td>2 x 52 / year</td>
</tr>
<tr>
<td></td>
<td><strong>Total number of samples</strong></td>
<td>2 x 52 / year</td>
</tr>
</tbody>
</table>
Clean-up Sampling

Samples obtained in two major periods

- **1\textsuperscript{st} period (natural flow)** → 17 samples
- **2\textsuperscript{nd} period (artificial lift)** → 75 samples

- 17 obtained:
  - 7 analyzed oil
  - 2 analyzed water

- 75 obtained:
  - 15 analyzed oil
  - 25 analyzed water
Well lay-out

Well trajectory and tracer placement

OS-1 / WS-1 (ROS-408 / RWS-448) – toe section
OS-2 / WS-2 (ROS-411 / RWS-449) – middle section
OS-3 / WS-3 (ROS-410 / RWS-450) – heel section
Interpretation

Oil tracer response
Interpretation

Oil tracer response – 2\textsuperscript{nd} period details

- Strong oil wetting for OS-1
- Effective clean-up from toe section
Interpretation

Water tracer response
Interpretation

Water tracer response – 2\textsuperscript{nd} period details

• Large response from WS-3 indicates large water wetting
• Absence of flush-out response in heel and mid section
Interpretation

• All oil tracers are detected in most samples with sufficient oil
• All water tracers are detected in most samples with sufficient water
• Strong oil response from toe section
• Weak oil responses from mid and heel sections
• Large oil / water ratio in toe section
• Strong water response from heel section
• Mid section giving the weakest response
Lessons Learnt

• Regular meetings between all the involved parts beneficial
• Thorough understanding of monitoring objective needed
• Logistic aspects:
  • Tracers rod assembling
  • Tracers carrier sub assembling
  • Samples shipment
Conclusions

- The first RESMAN intelligent chemical inflow tracer installation was successful.
- The system gave information on flow contribution without prior knowledge of the success of the fracturing jobs.
- No impact on the overall completion design and operations.
- No environmental impact.
- As of now, analysis has been carried out only for samples from the clean-up phase.
- Further information will be obtained from the analysis of samples taken during production phase.
Aknowledgements

• Stefano Di Vincenzo – Completion Manager eni E&P
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• Daniele Magherini – WOM eni Congo
• Einar Storli – PM RESMAN AS
• Kristoffer Brække – Technical Director i-Tec

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