Multidisciplinary Workflow applied to Multiple Stage Hydraulic Fracturing of Horizontal Wellbores: Evolving the Process in the Lebada Field, Black Sea

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Agenda

- Why is reservoir contact important?
- Lebada Fields Offshore Black Sea
- Evolution of the Completion Process
- Offshore Multi-frac Completion Challenges
- Horizontal Multi-frac Completion Solutions
- Production Results
- Conclusions
Why is reservoir contact important?

- Single stage vertical well frac vs. horizontal well multiple stage fracturing

Maximize reservoir contact
- Increase recoverable reserves
- Increase production
Lebada Fields Offshore Black Sea

- Cretaceous age: carbonate/shale/sand
- Oil and gas reservoir
- Permeability: 0.001 to 2 mD
- TVD: 2,000 m
- BHST: 93 degC
- Producing since early 90’s
Evolution of the Completion Process

Conventional Completion

- Vertical Wells
- Cemented and Perforated Liner
- No Stimulation Applied
- Economics depended purely on good reservoir quality and oil prices
Evolution of the Completion Process

**Matrix Stimulation**
- Platform pumps and equipment
- Retarded and non-retarded HCl acid based system
- 2-3 fold production increase, fast production decline
Evolution of the Completion Process

**Conventional Completion**

- Land based equipment placed on platform and boat deck
- Single stage prop fracturing with polymer based fracturing fluids
- Up to 6 fold production increase yet short term production results

**Matrix Stimulation**

**Hydraulic Fracturing**

- Land based equipment placed on platform and boat deck
- Single stage prop fracturing with polymer based fracturing fluids
- Up to 6 fold production increase yet short term production results

**Technical Limit Reached**
Evolution of the Completion Process


Conventional Completion
Matrix Stimulation
Hydraulic Fracturing
Hz Multistage Fracturing

Reservoir
Surface
Vertical Wells
Horizontal Wells
Evolution of the Completion Process

- Conventional Completion
- Matrix Stimulation
- Hydraulic Fracturing
- Hz Multistage Fracturing
- Hz Massive Fracturing

5 or more stages in a single well
Offshore Hz Multi-frac Completion Challenges

Drilling Optimization
- Stay on target
- Minimize severe dog legs
- Optimize ROP

Multi-service Coordination
- Integration of MWL, LWD, WL data
- SLB-Client interface management
- Fast response data analysis

Completion Process
- Selection of the right completion system
- Data acquisition & analysis
- Formation Characterization

Fracturing Process
- Hydraulic Fracture Modeling
- Design & Pumping Schedules
- Offshore fracturing logistics
Horizontal Multi-frac Completion Solutions

Completion Optimization

Selection of the right completion system

OPEN HOLE FRAC SYSTEM:
- Up to 6 frac stages
- Full wellbore access
- Re-closable & mill-able frac ports
- Flexible packers positioning
- Continuous operation
Completion Optimization

Selection of the right completion system

Data acquisition & analysis

Model Setup → Real Time Data LWD or WL → Quality Control

Interpretation

- Petrophysic
- Borehole Geology
- Sonic
Horizontal Multi-frac Completion Solutions

Completion Optimization

Selection of the right completion system

Data acquisition & analysis

Formation Characterization

DETAILED OUTPUTS

- Lithology
- Fluids Saturation
- Porosity
- Permeability
- Wellbore Shape
- Faults & Fractures
- Stress Profile
- Static YM & PR
- Fraccability
Horizontal Multi-frac Completion Solutions

Fracturing Process

Hydraulic Fracture Modeling

KEY FACTORS:
- Initiation point
- Frac length
- Conductivity
- Height growth containment
Horizontal Multi-frac Completion Solutions

Fracturing Process

Hydraulic fracture monitoring

Design & Pumping Schedules

KEY FRACTORS:

- Polymer free fluid
- On-the-fly mixing
- Fluid rheology
- Proppant transport
- Proppant flow back control
- Fluid leak-off
- Material balance
- Frac fluids flow back

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<tr>
<th>Stage</th>
<th>Pump Rate (m³/min)</th>
<th>Fluid #</th>
<th>Fluid Name</th>
<th>Gel Conc. (lb/mgal)</th>
<th>Fluid Volume (m³)</th>
<th>Prop. #</th>
<th>Prop. Conc. (PFA)</th>
<th>Prop. Mass (kg)</th>
<th>Slurry Volume (m³)</th>
<th>Pump Time (min)</th>
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Horizontal Multi-frac Completion Solutions

- Over 400 Tons of proppant
- Over 100 m³ of chemicals
- All loaded in vessel for single trip
Production Results

To date the described workflow for OH Multi-stage frac has been applied in 5 wells in the Black Sea:

<table>
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<th>Well Name</th>
<th>Date</th>
<th>Number of stages</th>
<th>1st Month Production</th>
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<td>Well #1 – New well</td>
<td>June 2008</td>
<td>3 Fracs</td>
<td>80 Tons/day</td>
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<td>Well #2 – New well</td>
<td>August 2009</td>
<td>3 Fracs</td>
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<td>Well #3 – Re-entry</td>
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<td>60 Tons/day</td>
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<td>Well #5 – New well</td>
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<td>6 Fracs</td>
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Conclusions

- Lebada Field *completion process continues to evolve* to reduce the cost/bbl

- **Massive multi-stage fracturing** is now a reality in the Black Sea

- *Image and sonic logs interpretation are key* for the completion and frac placement

- The *Multidisciplinary workflow and methodology is crucial* for the completion success

- Multi-stage Hz completions proven to provide **much better economics** than previous approach.
Thanks!