Well Architecture Driven Transverse Shear Stresses - Engineering Challenges in ERD Well

HALLIBURTON LIFE 2019

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Introduction

BUSINESS AREAS
• Upstream Oil & Gas
• Renewables

HISTORY
• Founded in 2005
• Head Quarter in Copenhagen

VALUE DRIVERS
• Quality Engineering
• Operational Performance
• Motivated Professionals
• Value Adding
• Customer Satisfaction

TRACK RECORD

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<table>
<thead>
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<tbody>
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<td>Clients</td>
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QUALIFICATIONS

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OFFICE LOCATIONS

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<td>Mumbai</td>
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Sketch - LIFE

Launch  Issue  Fix  Evolve
Well Overview

- Extended reach Well
- Location - Offshore Denmark
- 23000 ft. well depth with 14500 ft. lateral
- Lower cretaceous chalk (Marly) (condensate rich gas)
- Well Architecture -
  - 10 ¾” Production Casing
    - Allows expandable liner option.
  - 5 1/2” frac sleeve cemented liner
    - No tieback to surface.
Job

- Frac Sleeve completion / stimulation
  - Used in North America land shale plays.
  - Thousands of applications.
  - Coil Tubing operated.

- First in Denmark (Offshore)
  - Jointed drill pipe/ tubing work string planned
  - Frac BHA

- Specific differences
  - Frac. thru tubing
  - Under-displacement req. - reverse circulation
Challenge: Work string design for complex stimulation operation

Challenges:
- Mechanical (Tensile capacity)
- Torque (ability to rotate)
- Hydraulics Rev./Fwd. Circ.
- Fraccing (Rates/Pressure)
- Fishing (inside 5 1/2” Liner)
T/D – Quick Look

- WellPlan: Torque and Drag
  - Normal analysis modes
- Define String and Well components:
  - W/String: 5 ½” Drill pipe x 3 ½” Tubing x 3 ½” Frac Assembly
  - Dimensions, grade, material strength, capacities, ID’s etc.
- Define Well Fluid:
  - Heavy frac. fluid (13.60 ppg)
  - Completion fluid (8.60 ppg)
- Define Cased Hole Friction Factors:
  - Sensitivities: Friction factor 0.10 – 0.20
  - 0.25 Max. friction factor for detailed look into
Key Observations

"Needle Effect"

String depth ~ TD, Abnormally high side force occurred around the bend
Key Observations

Torque/Drag Stresses Plot

- Bending Stress Peak
- Tr. Shear Stress Peak
- Tri-axial Stress Peak
Technology Scouting

Software Capabilities

Modelling Accuracy

Simulation Sensitivity
Detailed Investigation

- Torque/Drag Model
  - Stiff string algorithm
- Tortuosity model
  - Offset/Analogues
  - Random incl. dependent azimuth
- Run Parameters:
  - Tripping In
  - Slide drilling mode (non rotating) – 5.0 – 10.0 kips
- Torque/Drag analysis modes
  - Normal analysis
  - Drag chart
    - 500.0 ft incremental in horizontal leg
Analysis Parameters

- State of work string in worst case
  - RIH and Slide Mode

- Assumptions
  - Cased hole FF – 0.20/0.25
  - Tortuosity Magnitude 1.43 – 1.93 (1.53)
  - Work string travel – 14000 – 23000 ft. MD
Detailed Analysis

String Travel

Drag forces @ incremental string depth

Key Observations:
1. Drag forces increase almost linearly with string depth
2. No lock up flagged at any simulation step
3. String weight available to slack off to overcome the drag
4. Work string in relatively stable state with less friction factor 0.20 or less
Detailed Analysis

Max. T/Shear Stresses

Joints of 3 ½” Tbg. - High stresses
Detailed Analysis

String Travel

Max. VME Stresses

Key Observations:
1. Max VME Trip in 0.20 FF: Sinusoidal and Helical buckling. No string failure flagged.
2. Max VME Slide Drill 0.20 FF: Helical buckling. Yield failure at 22500 ft MD.
3. Max VME Trip in 0.25 FF: Helical buckling. Yield failure at 22500 ft MD.
4. Max VME Slid Drill 0.25 FF: Helical buckling. Yield failure at 22000, 22500 ft MD.

WellPerform

Joints of 3 ½” Tbg. - High VME stresses
Transverse Shear

Transverse Shear Stresses

- Stress magnitude determined by \( \sigma_{\text{tr}} = 2 \times \frac{F_N}{A_s} \)
  - Not torsional shear stress that acts circumferentially
  - It’s perpendicular force – alike shear rams

- What is causing high Transverse shear stresses “Needle Effect”
  - Needed to investigate further

- What is the Failure Limit and what Safety Factor should we use?
  - API RP 7G = 0.577 \times \text{SMYS}
  - Safety factor 1.25 for 110 ksi SMYS Tubing
  - Transverse Shear Stress limit = 0.5 \times 0.8 \times 110000 = 44000 \text{ psi}
Transverse Shear

Cake / Knife Example
Compression generates point load

Stationary Knife (sharp edge)

True Tension Plot: RIH and Slide mode
Solution / Fix

- Tapered Well Architecture 10 ¾” x 7” x 5 ½”
- Cased hole friction factor 0.15-0.20
  - Yield failure can happen at high friction
  - Design fluids with friction reducers
  - Calibrate friction factors
  - Real time Torque/Drag modelling
- Reduce horizontal leg < 21000
- Min. Slack off @ frac. BHA < 10.0 kips
- Control tortuosity in the horizontal leg – geo-steering
Results – Tapered Scenario

Significantly lesser side force

Max. Side Force as Point Load @ incremental string depth

Key Observations:
1. Side force as a point load is significantly reduced in a Taper Well architecture
Results – Tapered Scenario

Significantly reduced transverse shear stresses
Results – Tapered Scenario

VME Stresses reduce significantly FF 0.10-0.20
Summary

Solution/Fix

Taper down 10 ¾” x 7” x 5 1½”

Keep friction low

Min. Slack off

Optimize Lateral length
Scope / Evolve

Transverse shear failure limit
- Based on API RP 7G (torsional shear)
- API TR 5C3?
- Brittle behavior

Failure limit de-rate?
- Due to Tension/Compression
- Due to Temperature
- With bending

What is the Safe operating limit?
- Tool joint limits same as pipe body?
- No. of cycles (Reciprocal)

Shuffle heavy weights?
- Around the well bend
- Higher cross section area
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