LINQX

Case Study

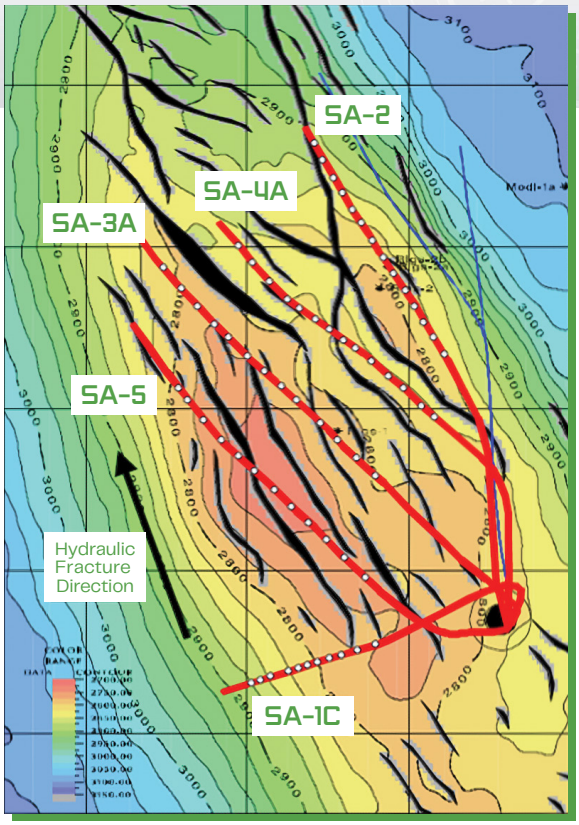
Hydraulic Fracture Complexity Evaluation and Field Implementation Optimization in South Arne Chalk Horizontal Wells Using FracPro

Overview

Hydraulic fracture and field implementation changes were analyzed using FracPro software to evaluate the complex nature of induced fractures and the adverse effects of natural fracture reactivation in the South Arne Field chalk reservoir. Effectively addressing these factors was crucial for the successful stimulation and placement of high concentrations of proppants into the Tor and Ekofisk chalk formations.

Challenges

Unlike other North Sea chalk reservoirs, where the primary issues are tortuosity and the generation of multiple fractures, wells in the South Arne reservoir face a unique challenge. The activation of natural fractures or fissures leads to excessive stimulation fluid leak-off, compromising the placement of the high proppant concentrations required to create a proper conductivity contrast between the fracture and reservoir.



Cipolla et al., SPE 62888, SPE ATCE 2000, Dallas, Texas.

Solution

As shown in the South Arne Field map, a detailed stimulation process analysis of four wells—performed using FracPro software—highlighted the importance of using higher volumes and high concentrations of 100-mesh sand as part of the pad stage. This approach counteracted the excessive fracturing fluid leak-off during fracture stimulation. Additionally, employing this strategy enabled the placement of higher proppant concentrations using the Tip Screen-Out (TSO) technique, mitigating the negative effects of proppant embedment typically observed in chalk formations.

Analysis Results and Benefits

The integration of hydraulic fracture treatment behavior, rock mechanics properties, and pressure decline analysis using FracPro software revealed that the activation of existing fissures or natural fractures in the reservoir was the primary cause of hydraulic fracture treatment failures. To mitigate the excessive fluid loss and fracture complexity associated with this issue, 100-mesh sand was applied at higher-than-normal concentrations (3 to 4 pounds per gallon [ppg]). This strategy successfully enabled the execution of 64 treatments in the field, resulting in effective well stimulation and enhanced productivity.

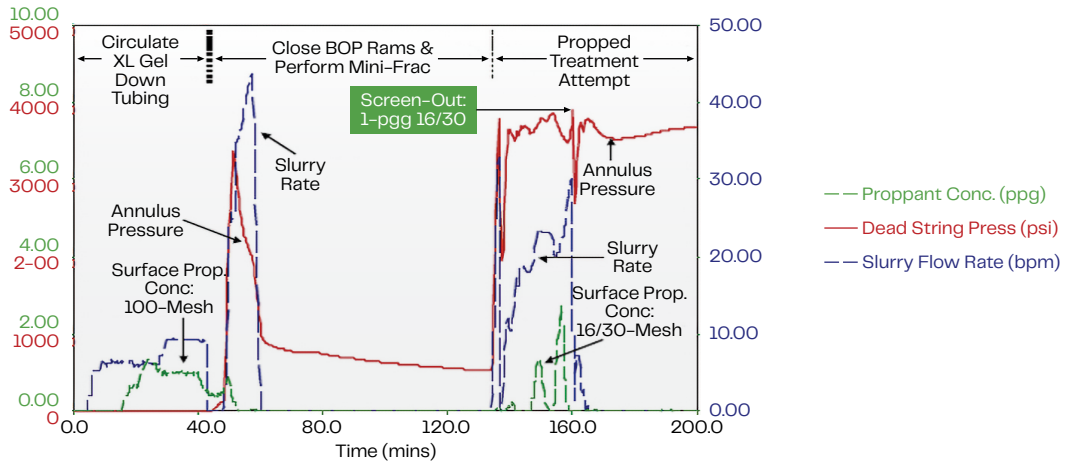
Analysis and Treatment History

This study and fracture stimulation optimization involved five wells, with SA-1C serving as the initial case in which fracture stimulation challenges were identified. For the sake of case history documentation, only selected stages from each well will be discussed. For more detailed information about all stages analyzed, please refer to SPE Paper 62888.

The first fracture treatments in the South Arne Field were conducted in Zones 2 and 3 of the SA-1C well. Unfortunately, all fracture stimulation attempts in both zones were unsuccessful.

Well SA-1C Zone 2

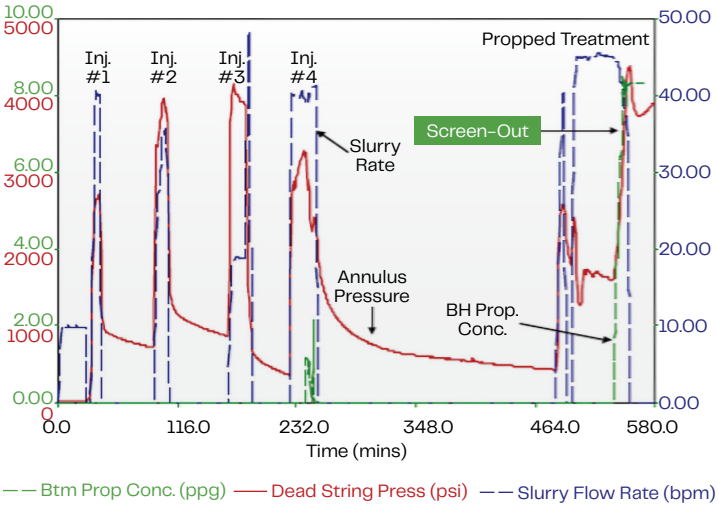
The treatment screened out with a proppant slug concentration of 1 ppg (16/30 mesh).



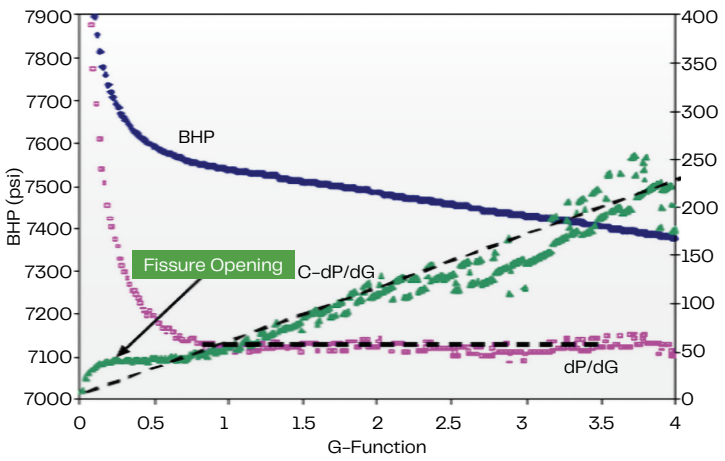
SA-1C Zone 2 Treatment Screen-Out (from SPE Paper 62888)

Well SA-1C Zone 3

The treatment screened out with only 130 Klbs of 16/30 mesh proppant, creating incipient fracture geometry and limited conductivity.

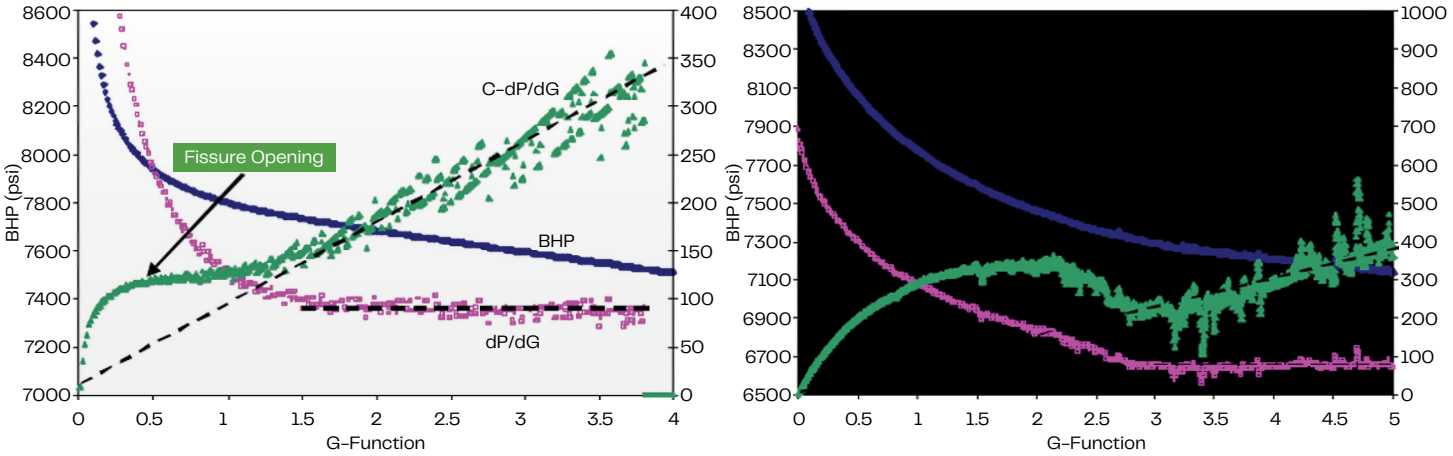


SA-1C Zone 3 Treatment Screen-Out (from SPE Paper 62888)



SA-1C Zone 3 Treatment 1 Pressure Fall-Off Analysis (from SPE Paper 62888)

Detailed pressure fall-off analysis revealed that the proppant placement issues were caused by the interaction between the hydraulic fracture and existing natural fractures or fissures, rather than by fracture complexity near the wellbore.

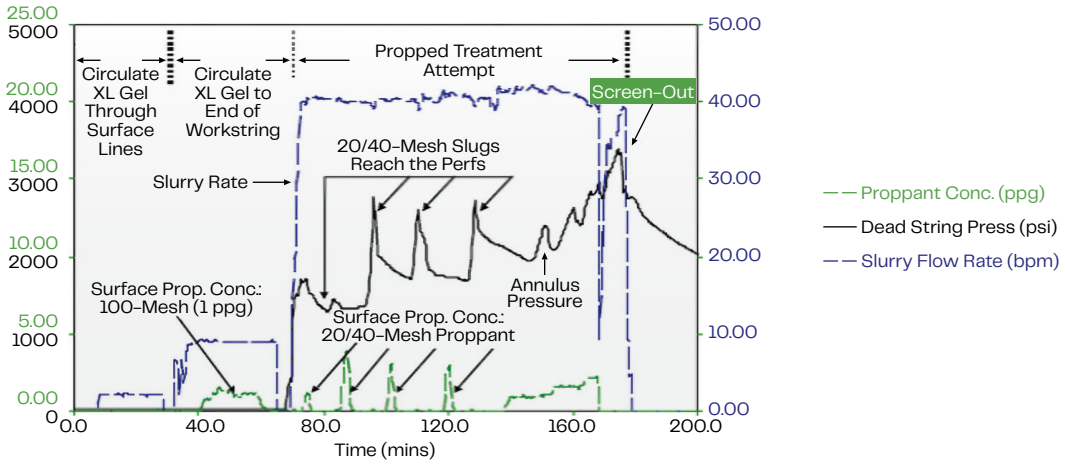


SA-1C Zone 3 Treatment 1 Pressure Fall-Off Analysis (from SPE Paper 62888)

Another hydraulic fracturing treatment was attempted in the SA-4C well, incorporating modifications to improve fracture initiation and execution strategies.

Well SA-4C Zone 1

- **Approach**: A reduced perforated interval of 1 foot was used.
- **Execution**: Crosslinked gel initiated the fracture, followed by 1-ppg of 100 mesh sand to reduce fracture complexity and manage fluid loss..
- **Outcome**: Despite using 20/40 RCS instead of 16/30 proppant, only 20% of the planned proppant was placed due to early screen-out tendencies.

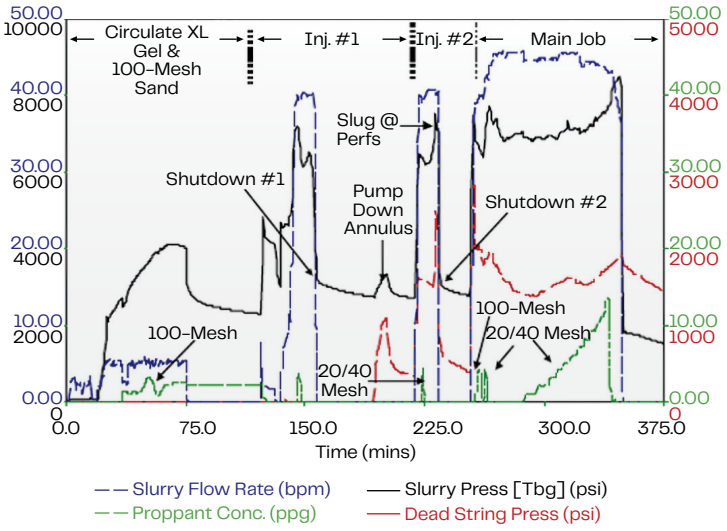


SA-4C Zone 1 Hydraulic Fracture Treatment History (from SPE Paper 62888)

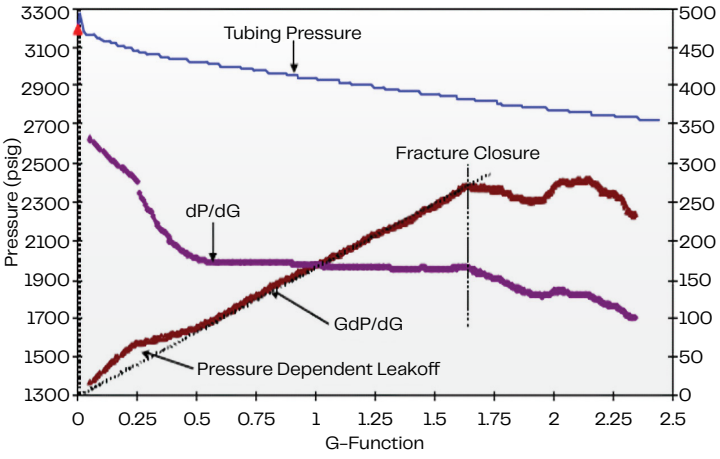
Well SA-4C Zone 2

- **First Attempt**: The strategy included ramping the 100-mesh sand concentration from 1 to 4 ppg and using 1-to-3 ppg of 20/40 proppant. The treatment was aborted due to annular plugging.
- **Second Attempt**: After cleaning the plug, the fracture treatment was reinitiated using a 1-to-6 ppg 20/40 RCP proppant slug. Pressure behavior suggested restricted passage, necessitating further pressure fall-off analysis.

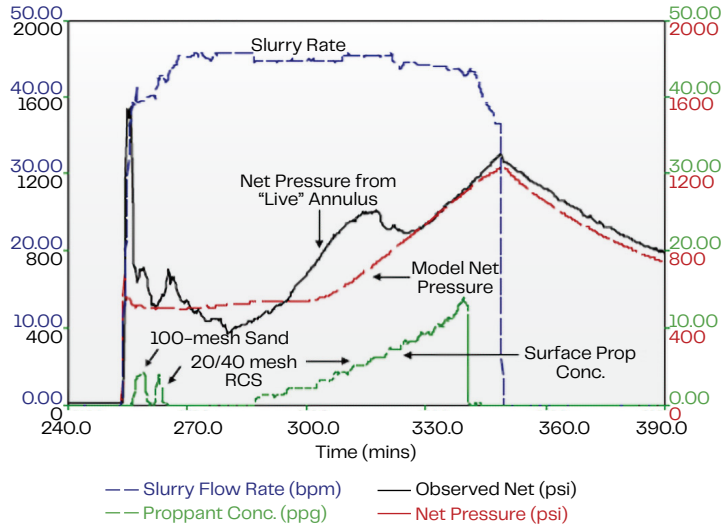
- **Final Attempt**: A modified strategy with 1-to-4 ppg 100 mesh sand in the pad and 20/40 RCP to pack the fracture successfully placed 450 Klbs of 20/40 RCP proppant at a maximum concentration of 12 ppg. During the TSO process, a pressure increase of 500 psi was observed.



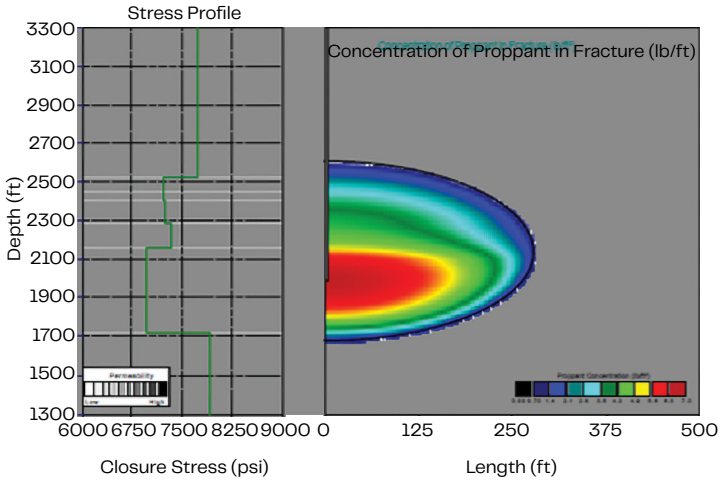
SA-4C Zone 2 Hydraulic Fracture Treatment History
(from SPE Paper 62888)



SA-4C Zone 2 Injection 1 Pressure Decline Analysis
(from SPE Paper 62888)



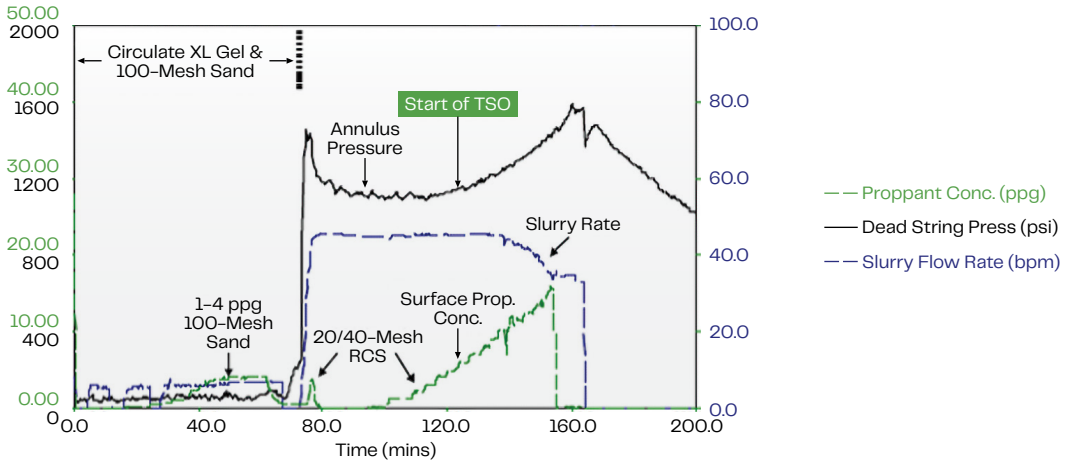
SA-4C Zone 2 Hydraulic Fracture Net Pressure Match
(from SPE Paper 62888)



SA-4C Zone 2 Predicted Fracture Geometry
(from SPE Paper 62888)

Well SA-4C Zone 3

- **Approach**: Lessons learned from Zone 2 were applied.
- **Execution**: Pad stage included 1-to-4 ppg 100 mesh sand, followed by 1 to 4 ppg 20/40 proppant to evaluate proppant passage.
- **Outcome**: The main treatment successfully placed 500 Klbs of 20/40 RCP proppant at a maximum concentration of 15 ppg. During the TSO process, a 500 psi pressure increase was observed.



SA-4C Zone 3 Completed Fracture Treatment (from SPE Paper 62888)

The successful hydraulic fracturing strategies implemented in SA-4C were subsequently used to stimulate additional wells.

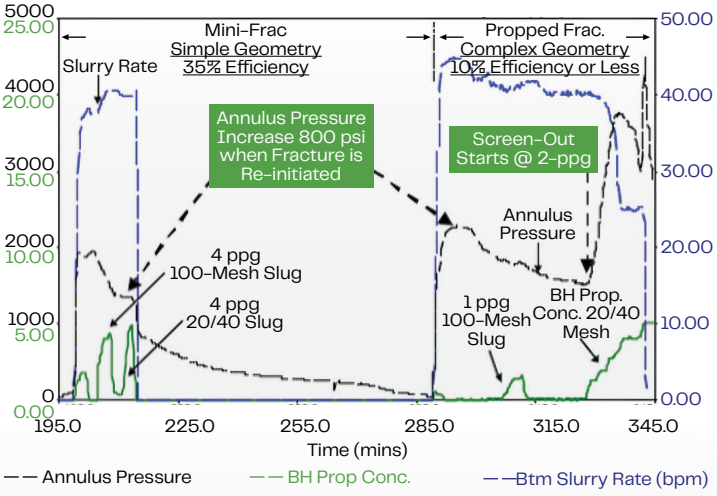
Well SA-5B

The fracture stimulation strategy from SA-4C was successfully applied to SA-5B, where 12 hydraulic fractures were performed effectively.

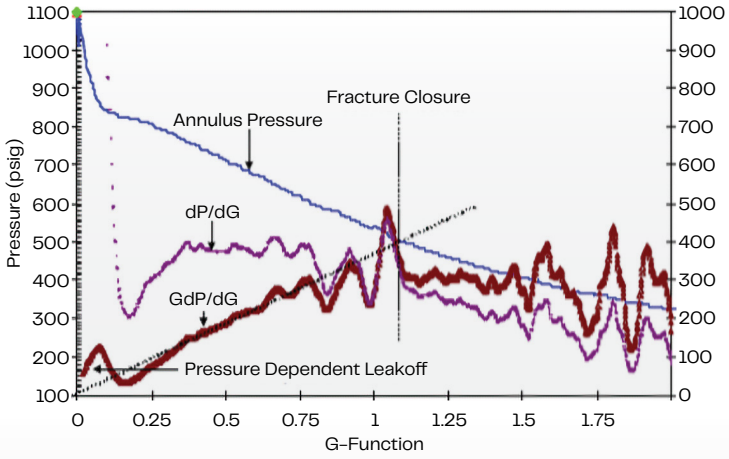
Well SA-2, SA-4, SA-1C, and SA-3 (Batch Completion)

The stimulation strategies developed for SA-4C and SA-5B were applied to SA-2, SA-4, SA-1C, and SA-3 wells in a batch completion process. This resulted in:

- The successful stimulation of 64 zones.
- The placement of 49 million pounds of proppant.



SA-3C Zone 1 Treatment Rate-Pressure History (from SPE Paper 62888)



SA-3C Zone 1 Mini-Frac Analysis (from SPE Paper 62888)

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