**Case study:** Norway

Baker Hughes

# Efficient single run – multi ball seat PRIME Milling operation

A North Sea customer had a new and critical offshore water injection well which was not performing as expected, having an injection rate well below target.

Drilled in 2020, the well had a lower completion comprised of four frac sleeves in the horizontal section. An LWI operation was carried out in 2021 to inspect the completion – to evaluate the ball seats and valve status, plus any blockage that might be present, and to determine the required intervention scope going forward.

During this operation a camera diagnostic tool was run. This observed the presence of some debris, and the toolstring got held up just below the upper ball seat requiring an overpull to come free.

A subsequent LWI operation was then planned for 2022, to mill out all four ball seats and perform a multi zone perforation operation across all zones to generate the desired and expected injectivity rate. As per such a completion design, ball seats of reducing sizes were deployed in the lower completion of this well ranging from 3.403” ID for the uppermost to 2.697” ID for the lowermost. Despite that, the customer wanted the efficiency of a single run solution to execute the entire milling operation.

## Solution

In order to achieve this, a multistep mill of appropriate sizing was designed – one that would have the dimension range required to engage appropriately with all four ball seat sizes in the well completion, milling them all out to a common maximum ID. This would then enable passage for subsequent deep penetrating or big hole perforation charges to be run. The design of the step mill would provide both lower and upper tapered sections for back-reaming application.

The multistep mill would be deployed on electric line as part of an electrohydraulic powered mechanical toolstring comprised of components from the **PRIME Technology Platform,** incorporating a high level of instrumentation for real-time measurement and control of parameters that are critical to milling optimization. The **PowerTrac PRIME Tractor** would provide high speed toolstring conveyance of the milling assembly to task depth. Once there, it would then provide rotational anchoring and weight-on-bit (WOB) in support of the milling task across the horizontal well section.

Tension/compression subs placed above and below the tractor would provide in-situ measurements of the WOB throughout the operation. The **PRIME Direct Drive Rotation** device would provide the rotational torque.

Monitoring and adjusting the torque, WOB, and rotational speed in real-time would enable an optimized rate of penetration throughout all steps across all ball seats, handling the spread of ball seat dimensions confronted during operation. The weight on bit would be adjusted by regulating tractor forward force, to keep the milling rotational speed and torque within the optimum operating range that was determined during pre-job tests.

## Challenges

- A new and critical offshore water injection well was not performing as expected, having an injection rate well below target
- The customer wanted the efficiency of a single run solution to execute the entire milling operation

## Results

- Precise and efficient ball seat milling job enabled full access for subsequent perforation operation, delivering improved injectivity in a critical well
- Precision multistep mill configured for the operation
- Four ball seats milled in an “all in one run” solution

A **PrecisionStroker** was also added to the toolstring to enable immediate high force pulling capability to free the toolstring if it were to get stuck in hole. As a further precaution, controlled release subs were also included in the string. Neither of these contingency measures were required for the operation.

Thorough pre-job tests were carried out at our engineering facility on identical ball seats that were placed in a test-jig set up.

During these tests, the key toolstring parameters were recorded as well as physical and visual inspections carried out to monitor mill wear as well as ball seat milling progress and condition.

The time required to mill through each ball seat was also captured, this to determine the overall efficiently of the milling solution, and to determine optimized tool parameters to be used for the actual operation.

The swarf produced by the milling operation was found to be powder like, leaving no concern with regards to hindrance of the subsequent electric line perforation runs or a detrimental impact on the well injectivity.

Critical tool parameters captured in real-time during the testing provided clarity and understanding of the milling sequence of each ball seat, with mill engagement and breakthrough of each mill clearly determined from the multitude of toolstring data curves available.

Typical indications of milling progress seen via surface readout are user-increased weigh-on-bit resulting in increased milling torque and reduced milling rpm; and increased downhole wireline tension as the tool mills further into the ball seat.

## Results

All four ball seats were milled out successfully in a single run operation, with the toolstring providing both milling and back reaming across all ball seats, this ensuring no sharp edges remained as a result of the operation. Milling times for each ball seat ranged from 17 minutes for the uppermost to 1 hour 45 minutes for the lowermost. The extended times observed on the lower ball seats were attributed to increasing debris within the well, however the milling times delivered were far below those the client had experienced on previous operations.

Upon return to surface little to no wear was found on the step mill and all mill sections were found to still be well in gauge. In effect, the step mill was used as a drift run prior to carrying out the perforations. Following the operation the injectivity was increased, this contributing to increased production from neighboring producer wells.

**Example log data taken from a pre-job test done at the onshore engineering facility**