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Risk based decision support for the planning of a challenging HPHT drilling operation

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Abstract

In the planning of a new appraisal well on an HPHT field on the Norwegian shelf, pressure control was at an early stage identified as a challenge. The pressure margin was expected to be narrow and pore and fracturing pressures were uncertain. This represented risks related to fracturing and losses and to kick and ultimately loss of well control.

To explore the extent of the risk, understand the most important factors contributing to risk and provide a basis for reducing risk through decisions in the operation planning, a quantitative risk analysis was commenced. Pressure control physics and the impact of uncertainties were explored through Monte Carlo simulation using the KickRisk analysis tool. With this tool probabilities are used to describe the uncertainty related to a number of operational, equipment related and geological pressure components. The output from an analysis reflects the ability to stay within the safe operational window during drilling, in terms of well specific kick and fracturing probabilities. The relative risk contributions from the different operational phases and from different kick and fracturing mechanisms in each phase are included.

This paper describes the application of the KickRisk analysis tool on the HPHT well. Specific attention is drawn to how the analysis supported the identification and selection of measures aiming at minimising pressure control risk. Such measures include risk-based mud weight selection, reinforcement of procedures and preparation of decision rules with respect to the outcomes of formation integrity testing and pore pressure measurement during drilling.

1. Introduction

Pressure control was a key issue in the planning of the reservoir section of an HPHT appraisal well on the Norwegian Continental Shelf. Narrow pressure margins and considerable

geologic uncertainties involved risk of mud loss, kick and ultimately blowout. Forthcoming decisions related to selection of mud properties and operational procedures would be a challenge, and the overall risk level of the drilling operation unclear. It was decided to undertake a quantitative risk analysis (QRA) with focus on pressure control in order to improve the understanding of the risk picture and to obtain a stronger basis for decision-making in the development of the drilling program.

The objective of this paper is to present the stages of the QRA in the well planning process, the results and their applicability as decision support for the project.

The appraisal well was to be drilled with a jack-up rig, i.e. excluding heave effects on the bottom hole pressure (BHP). The reservoir section was planned drilled with 8 1/2" drill bit, with the 9 5/8" casing set above the reservoir formation. Originally, tripping out of the well was planned with a slug and no circulation. It was first assumed that the well would be completed with screens. Later it was decided to run 7" liner. At the time of writing this paper, the drilling of the well was ongoing, but the reservoir section was still not commenced.

The QRA was performed by use of the KickRisk analysis tool. This tool is based on a pressure control model. Factors that influence the BHP throughout the various phases of the construction of a well section are decomposed. The model includes down hole, fluid, equipment and operator-related aspects and their impact on hydrostatic, friction and surge/swab pressure effects. The analysis implies gathering of input on the uncertainty of these quantities in terms of probabilities and probability distributions. By Monte Carlo simulation the resulting probabilities of entering a state of underbalance with the pore pressure (kick) and of exceeding of the fracturing pressure (fracturing) are derived, and the factors that are main contributors to risk may be identified.

The analysis was performed in 3 stages. Most of the input was gathered in the first stage and an overall risk picture was established. The two latter stages were updates on decisions on equipment, design and procedures introduced through the project.

Some more details on the analysis tool are included in Section 2. Section 3 expands on the analysis process and the analysis results. Conclusions are summarised in section 4.

2. The KickRisk analysis tool

The ideas and approach behind the KickRisk analysis tool were developed in PhD project presented in 1995 /1/. The models and software have been subject to stepwise