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Extended Abstract

Determination of safe mud weight window and optimal drilling path in the Gadwan formation using rock failure criteria to minimize drilling challenges in one of the hydrocarbon fields in southwest Iran

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Abstract

Middle Eastern economies heavily depend on increasing crude oil production, shifting focus to optimizing output from existing fields due to the rarity of large hydrocarbon field discoveries. The Gadwan formation, a significant reservoir in the Abadan Plain, poses drilling challenges, particularly instability issues causing collapse, narrowing, and bit sticking. Over 90% of well problems in this formation relate to instability, resulting in increased non-productive time (NPT) and drilling costs. This study assesses well stability in southwestern Iranian oilfields using a one-dimensional geomechanical model based on well log data. Employing the Mohr-Coulomb and Mogi-Coulomb criteria, the study determines that the Mohr-Coulomb criterion provides a better estimate of collapse pressure. Sensitivity analysis suggests the optimal drilling direction for Gadwan formation is northwest-southeast, with a safe mud weight of 14.9 LB/G for vertical drilling. The results of this study can be used as a reference for determining the optimal mud weight window in planning future wells in this field to deal with drilling stability problems.

1. Introduction

Wellbore instability costs billions annually, leading to a 10% increase in drilling expenses. Comprehensive analysis of well stability is crucial, considering mechanical (stress, rock strength, drilling methods) and chemical factors. Factors like well trajectory and mud weight influence stability, and adjusting mud pressure helps prevent wellbore collapse [1]. Considering wellbore orientation based on existing stresses is vital. One-dimensional geomechanical modeling is employed to determine in situ stresses, establish a safe mud weight window, and optimize drilling paths. Various researchers, including Bradley (1979), have explored wellbore stability. Bradley introduced a 3D linear model for stability analysis. This study focuses on the Gadwan formation in a southwest Iran oil field, employing a 1D geomechanical model with GeoLog version 20 software. Parameters like elastic properties, rock strength, and in-situ stresses are calculated. The study determines the safe mud weight window and optimal drilling path for the target well using Mohr-Coulomb and Mogi-Coulomb failure criteria.

2. Methodology

In this study, a one-dimensional geomechanical model of the Gadwan formation was constructed using well log images. The available data on the in-situ stress magnitude and orientation, pore pressure, and mechanical properties of the rock were used to build the model. The model was validated and calibrated using all available data, such as caliper logs, image logs, and Modular Dynamics Testing (MDT). It accurately predicts shear failure around the wellbore with high precision. Then, to analyze the wellbore stability, the Mohr-Coulomb and Mogi-Coulomb failure

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criteria were used to compare the predicted instability with the actual wellbore condition, as shown in the image and caliper logs.

3. Results and Conclusions

Rock mechanical properties, crucial for geomechanical studies, include uniaxial compressive strength (UCS), adhesion, internal friction angle (φ), Young's modulus (E), and Poisson's ratio (v). Understanding these parameters is vital for assessing formation strength and stability around a wellbore. Mechanical properties are categorized as dynamic (determined through well logs) and static (obtained through laboratory tests like uniaxial or triaxial tests). A continuous log of predicted mechanical properties aids in evaluating natural variations in the studied layers. Elastic and strength parameters of Gadwan formation rock were calculated, and its pore pressure was estimated using the Zhang equation, calibrated with MDT test results. Stresses below ground include vertical (Sv), maximum horizontal (SHmax), and minimum horizontal stress (Shmin). Vertical stress is influenced by overlying sediments' weight, while horizontal stress results from geological and tectonic processes. Lithostatic pressure compacts rock vertically, inducing horizontal movement and affecting horizontal stresses. In formations without tectonic activity, minimum and maximum horizontal stresses are equal. In the presence of faults and tectonic activity, these stresses differ. Results of these calculations are depicted in Figure 1.

According to Figure 1, by comparing the obtained mechanical properties with the lithology of the formation, it can be concluded that the rock mechanical parameters change with lithological variations. Regions dominated by shale have weaker geomechanical quality, making them prone to collapse during drilling. In contrast, areas dominated by limestone indicate higher and more stable geomechanical quality.

This study briefly discusses two criteria, Mohr-Coulomb and Mogi-Coulomb, and calculates optimal drilling mud pressure to prevent fracture or collapse (Fig. 1). A comparison of failure criteria shows that the Mohr-Coulomb criterion yields better optimal mud pressure results than the Mogi-Coulomb criterion for the Gadwan formation. Breakouts on the FMI image log and caliper log indicate numerous breakout intervals, signaling instability. Figure 1 demonstrates that the Mohr-Coulomb criterion predicts instability mostly within the breakout zone, while the Mogi-Coulomb criterion suggests a stable well without collapse. Sensitivity analysis of wellbore stability to drilling path deviation is vital for optimization. Polar Schmidt diagrams in Figure 2 display results, aiding in determining optimal drilling paths and mud weight changes to prevent shear failures or induced fractures.

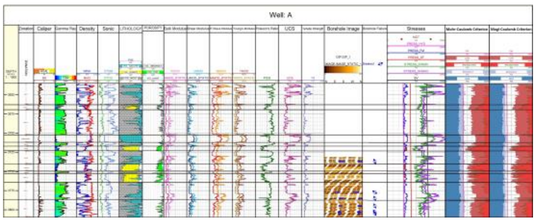

Fig. 1. Well stability analysis for Well-A. In most depths, the mud pressure line (PW) is located within the breakout zone.

The safe mud weight window for wellbore stability in Gadwan formation is 14.5 to 15.9 pounds per gallon according to the Mohr-Coulomb criterion. Optimal stability is achieved with a wellbore deviation towards the minimum horizontal stress (NW-SE) direction. For drilling direction (1) (N32W) at an inclination of 43 degrees, the minimum mud weight is 14.5 LB/G. changing to direction (2) (N58E) requires a maximum mud weight of 15.9 LB/G. Vertical drilling maintains stability with an optimal mud weight of 14.9 LB/G.

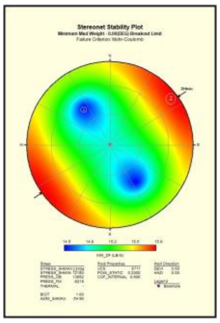

Fig. 2. The optimal drilling path and required mud weight changes for wellbore stability in the Gadwan formation

4. References

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