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Geomechanical Effects of Reservoir Pressure Drop and Drilling Fluid Temperature on Wellbore Stability Conditions

Ehsan Cheraghsahar, Reza Falahat* and Seyed Alireza Tabatabaei Nezhad
Faculty of Petroleum Engineering, Sahand University of Technology, Tabriz, Iran
rezafalahat@sut.ac.ir
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Introduction

Wellbore instability is one of the most important problems in drilling wells. Determining the proper safe mud window and the most stable trajectory can prevent or reduce this problem. The phenomena that cause wellbore instability are often divided into mechanical and chemical categories. From the mechanical point of view, to balance stresses, it is necessary to reduce stress around the well. For this purpose, by applying the weight of the drilling fluid column, this concentration decreases, and the wellbore tends to become stable. Chemical stability is also related to the chemical interaction of the drilling fluid with the formation. After production from the reservoir over time, the pressure of reservoir decreases and this issue can affect the values and even the direction of in situ stresses [1,2]. The change in the direction and amount of stresses has a great impact on the stability of the well. Therefore, in such a situation where the pressure of the reservoir has been reduced, to re-drill in this reservoir or extend the previous wells to increase the efficiency or to pass through this layer to reach the lower layers, it is necessary to reassess the wellbore stability condition and the optimal trajectory and considering the effect of reservoir pressure drop. Also, the drilling fluid temperature and chemical effect of drilling fluid affect the stability of the wellbore. The purpose of this research is to consider simultaneously the chemical effects and temperature of drilling fluid and the pressure drop of the reservoir on the stability conditions in one of the reservoirs in southwest of Iran.

Methodology

To determine the stability conditions of wellbore, it is necessary to first calculate the induced stresses around the well, then using a failure criterion, assess the stability of the wellbore. In this research, Mogi-Coulomb's three-dimensional failure criterion has been used [3].

Pressure Drop Effect

With the production of the reservoir over the years and in the absence of an injection program to control pressure, the pressure of the reservoir usually decreases. Reducing the pressure of the reservoir can cause changes in the amount and direction of horizontal stresses [4] which this influence stability condition. Therefore, to drill new wells through these layers, it is necessary to investigate the effect of reservoir pressure drop to reassess the well stability and optimal trajectory. Poroelastic equations can be used to predict the variation of stress due to reservoir pressure drop [5].

Drilling Fluid Temperature

The drilling fluid temperature is effective on induced stresses around the well, and high temperatures increase the thermal concentration, which has an adverse effect on the stability of the well wall. However, reducing the temperature of the drilling mud reduces the stress concentration around the wellbore. The inductive temperature stress induced by the fluid circulation temperature by Zoback is as follows [5]:

$$\sigma_T = \frac{a_m \times E \times (T - T_0)}{1 - \nu} \quad (1)$$

where and E are Poisson ratio and Young's modulus respectively. α_m is the temperature expansion coefficient of the rock (K^{-1}). T is the fluid temperature, and T0 is temperature of the formation (K°). This amount of stress caused by the temperature is added to the tangential and axial stresses around the wellbore.

Osmotic Effect

The chemical effect due to the difference in the water activity of shale and drilling fluid can be recognized as an equivalent of hydraulic potential [6]. Osmotic pressure calculations can help (to) determine the effect of chemical reactions on stress variations in wellbore [7].

In this research, first, the mechanical model of the earth was constructed in the initial conditions; afterwards, the minimum collapse pressure and the most stable trajectory were calculated using StabView software (design in static conditions). Then by considering the pressure drop of 11 MPa due to production and its effect on the stresses conditions, a new mechanical model is constructed, and the new minimum collapse pressure and the most stable trajectory are determined (design in dynamic conditions). In the third case, the osmotic effect and the drilling fluid temperature are considered separately on the stability conditions, and in the fourth stage, all factors are applied together and simultaneously.

Results and Discussion

In the initial condition of reservoir, minimum collapse pressure is in the range of 28.4 – 34.2 MPa and in the studied well is 33.2 MPa. Also, the most stable trajectory is a well with inclination of 45° and in direction of minimum horizontal stress (Figure 1(a)). After pressure drop of 11 MPa in reservoir pressure due to production overtime, in-situ stresses was changed (Figure 1(b)). This phenomenon cause change in stability conditions, as minimum collapse pressure in this condition is in range of 21.7 – 26.4 MPa, and the most stable drilling trajectory is in inclination of 35° and in direction of minimum horizontal stress. Also, the minimum collapse pressure in the studied well changed to 26 MPa.

Considering the effect of drilling fluid temperature and reservoir pressure drop, the minimum collapse pressure changed to 21.4-26 MPa, which is indicating that the lower temperature of drilling mud in comparison with the formation would reduce the required mud weight needed for stability of the wellbore.

In terms of osmotic effect, due to the fact that the drilling fluid in this research contains salt, the amount of osmotic effects is low, and the effects of ionic reactions between the drilling fluids and the shale content of the formation are negligible. In addition, the minimum required pressure in the well is in the range of 22-26.7 MPa.

If both factors are simultaneously considered, they can rather neutralize each other's effects. In the studied reservoir, in this research, the minimum required pressure in the well with respect to these two factors is in the range of 21.8-26.5 MPa, which shows a slight change in conditions without considering these two factors.

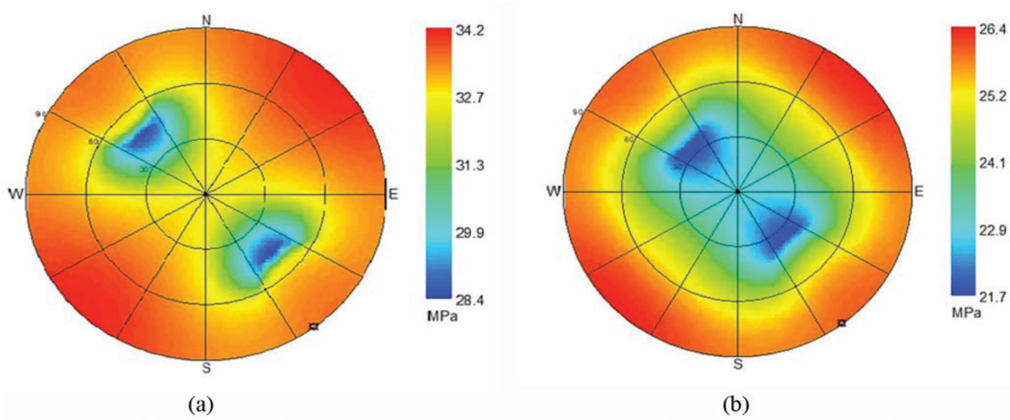

Fig. 1 Minimum collapse pressure: (a) initial condition and (b) after pressure drop.

Conclusions

In the case study under this research, the in-situ stresses was changed as a consequence of pressure drop of 11 MPa. Therefore, the induced stresses around the wellbore was changed, which significantly reduced the minimum collapse pressure range required for a stable drilling. The magnitude in all coordinates were decreased from around of 28.4-34.2 MPa to 21.7-26.4 MPa. In addition, in the well under this study, the minimum required pressure shows a decrease of 7.2 MPa in comparison with the initial conditions. The most stable trajectory for drilling in this area experienced a decrease of 10°. Hence, the pressure drop makes drilling the vertical well more stable compared with the horizontal well. Finally, investigating the osmotic effect and drilling fluid temperature simultaneously shows that these effects neutralize each other on the reservoir.

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