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A relationship to estimate the optimal drilling mud pressure in oil wells in carbonate formations of southern Iran oil fields

N. Behnam[1], M. Hosseini [2,*], S. Shahbazi[3]

[1] M.Sc. student, Department of Mining Engineering, Imam Khomeini International University
[2] Associate Professor, Department of Mining Engineering, Imam Khomeini International University
[3] M.SC. mining engineering, Department of Mining Engineering, Imam Khomeini International University

ABSTRACT: The analysis and prediction of well wall stability is considered as one of the most important and critical points in drilling operations. The instability of the well wall is one of the most serious problems in the oil and gas well drilling industry because it can lead to loss of part of the well or its entirety, which ultimately results in delays in operations, increased costs Drilling and delay will occur at the time of operation. One of the most important ways to cope with this problem is to determine the optimal drilling mud pressure. The pressure of the mud should be so high that it is in proportion to the amount of tension in the pores and pockets, and to the extent that the well after the large tensile fractures caused by the high pressure of the mud, as well as the shear fractures due to low pressure It will be safe. The aim of this study was to obtain a relationship to estimate the optimal drilling mud pressure in wells in the oil-rich regions of southern Iran. To achieve this goal, information of a number of oil wells was collected in the oil fields of southern Iran and then, using FLAC2D software, a limited-scale numerical program limited to oil wells, oil wells were analyzed in two Equilibriums and equilibriums modes have been investigated. Ultimately, for determination of the stability of the optimum drilling mud in the elastoplastic method, the method of determining the normalized level of NYZA has been used. In each step, optimal drilling mud pressure is calculated and finally, a correlation is presented using SPSS software through multivariate linear regression. This relationship is a linear relationship in which the optimal drilling mud pressure is estimated by parameters of minimum and maximum horizontal tensions, pore pressure, internal friction angle and cohesion.

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1. INTRODUCTION

Well drilling is the main process in obtaining access to petroleum reservoirs and petroleum production. The fact that the well passes through various layers with different properties makes the drilling a risky process. The instability of the wellbore during drilling through formations is one of the most expensive, serious problems faced by the oil industry. This issue can eventually cause delays in drilling operations, loss of production time and increase drilling costs. 5 to 10 % of the total annual costs of drilling, production, and operation of a well is related to the problems caused by the instability of the wellbore. The global costs of such problems are estimated at over two billion dollars a year, making research on this issue even more vital [1]. Due to the ever-increasing costs of maintenance required to stabilize the wall of oil wells, oil companies have shown more willingness to use open-hole wells (no stabilizer), making the identification of all the effective parameters on the instability of wells necessary. The effective parameters on the stability of the wall of oil wells include in-situ stresses, rock properties, drilling mud pressure and drilling path (direction and deviation from the vertical), some of which are manageable and others are not [2].

The methods used for the analysis of the stability of wellbore walls and the determination of the optimal pressure of drilling mud include using the failure criteria and numerical methods. The previous research and literature in this regard include a study by Shahbazi on numerical modeling of wellbore behavior in shale formations for an oil well in Marun field [3], a study by Sasaninia et al. on determining the optimal interval for drilling mud pressure using the FLAC^{2D} in an oil field in south western Iran [4], a study by Farzai et al. on determining the optimal drilling mud pressure in Kangan and upper Dalan formations based on the core data [5], a study by Asgari et al. on analyzing the stability of wellbore and determining the range of mud weight using the NYZA method in an oil field in southern Iran [6], Study by Fatemi Aghda et al. on determining the drilling mud drilling mud weight to increase the stability of the wellbore walls in an oil field in south western Iran [7], a study by Movahedinia et al. on the calculation of optimal mud pressure using various failure criteria for an oil well in Salman oil field [8], study by Asgari et al. on the stability of the well and determining the optimal mud pressure in an oil field in southern Iran[9], study by Chamanzad et al. on geomechanic modeling and determinination of safe mud

*Corresponding author's email: mahdi_hosseini1@ikiu.ac.ir

window for an oil well in Azadegan oil field [10], study by Maleki et al. on determination of optimal mud weight using the mohr coulomb-failure criterion in order to stabilize the oil wells in an oil field in southern Iran [11]. Library studies show that so far no relationship is proposed for estimation of the optimal drilling mud pressure in carbonate formations of oil wells in oil fields of southern Iran. This is considered one of the points of this study. The aim of this study is to provide a relationship for the estimation of the optimal drilling mud pressure in carbonate reservoirs of oil wells in oil fields of southern Iran.

3. NUMERICAL MODELING AND ANALYSIS OF RESULTS

In this study, stability and optimal drilling mud pressure of 16 wells in the oil fields of southern Iran are investigated using FLAC^{2D} software in three drilling modes of drilling with no mud weight, underbalanced drilling, and overbalanced drilling. In all the models, for each well, four different amounts of mud pressure were calculated, which include two mud pressures of 0.69 and 1.38 higher than pore pressure for overbalanced drilling and two mud pressures of 0.69 and 1.38 lower than pore pressure for underbalanced drilling. To analyze the results obtained from modeling, the Normalized Yielded Zone Area (NYZA) is used. In this method, the changes in plastic zone around the well resulted by pressure from different muds, including the model outputs from the FLAC^{2D}, were transferred into AutoCAD. Then, the plastic zone size (Normalized Yielded Zone Area) around the wellbore wall was calculated for the different pressures of mud and. By dividing them by the initial area of the well, the NYZA value was calculated for the different mud pressures. Finally, after drawing the NYZA graph with respect to drilling mud pressure of each well, the optimal mud pressure was calculated for all 16 wells. Then, SPSS software was used to analyze the data and obtain the estimated optimal pressure of the drilling mud through multivariate linear regression. The relationship derived from this model is as follows (Eq. 1):

$$P_{mud}=18.893+0.91(P_p)+0.281(\sigma_{Hmax})-0.224(\sigma\_hmin)-16.887(\tan\varphi)-0.82(C) \quad (1)$$

In this relationship, P_{mud} is the optimal drilling mud pressure in MPa, P_p is the formation pore pressure in MPa, σ_{Hmax} maximum horizontal stress in MPa, σ_{hmin} is the minimum horizontal stress in MPa, C is the cohesion and φ is the angle of internal friction.

In the end, there are tests to verify the proposed relationship for controlling the regression relation, all of which were carried out for the proposed relationship. The results indicate the validity of the proposed relationship. Also for the validation of the proposed relationship, three wells have been investigated from the oil fields of southern Iran. The difference between the drilling mud pressure presented in the results of previous literature and the optimal mud pressure obtained from the proposed relationship is very small and is regarded as negligible in the drilling and stabilization operations of wellbores.

3- CONCLUSION

The results of this research are:

1. The modeling conducted for well 14 showed that the displacement of the wellbore wall by drilling in the absence of mud pressure was 2.165 x 10-2 m, in overbalanced drilling it was 2.152 x 10-4 m and in underbalanced drilling it was 1.355 x 10-4 m. It can be seen that in drilling with mud pressure compared to drilling in the absence of mud pressure, the amount of plastic surface, as well as the displacements around the well in the underbalanced and overbalanced drilling modes were reduced greatly. The overbalanced drilling mode showed a greater reduction compared to underbalanced drilling mode.
2. According to the NYZA diagram, it can be understood that the amount of mud pressure is inversely proportional to the amount of NYZA and with the increase in mud pressure, the NYZA rate decreases and wellbore wall stability increases.
3. This relationship is a linear relationship that estimates the optimal drilling mud pressure with respect to the minimum and maximum horizontal stresses, pore fluid pressure, cohesion, and internal friction angle.
4. In this relationship, the pore fluid pressure showed the greatest contribution, compared to the other parameters, to the estimation of the optimal drilling mud pressure.
5. Considering the amount of NYZAs obtained for different mud pressures, it can be concluded that the optimal NZYA value for stability in the oil fields of southern Iran is between 0.05 and 0.5. It can also be concluded that the mean NZYA for underbalanced drilling is 0.26 and for overbalanced drilling is 0.22.

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