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Physical Modelling of Oil Wells During Drilling Using Designed Triaxial Cell

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ABSTRACT: Behavior prediction of oil well during drilling is important to prevent of instability problems and lots of cost spending. One of the problems can be pointed is failure of oil well wall during drilling. Thick-walled hollow cylindrical specimens can be able to modelling failure of oil well wall during drilling. Different triaxial cells exist for this test in world. Cell was used is designed based on Hoek cell. The benefits of this cell are ability of oil well during drilling and hydraulic fracture modelling. Also it is possible to measure the tangential strain in the center hole. This feature simultaneously is absent in most triaxial cells. To evaluate the performance of this cell, gypsum and concrete hollow cylinder specimens were made to modelling of oil wells during drilling. Literature studies and experimental results showed that, depending on the magnitudes of the applied internal pressure, external pressure and axial load, any of the radial, tangential and axial stresses induced in the cylinder considered as minor, intermediate or major principal stress. Hence, in this paper, two different stress conditions were used that consist: $\sigma_\Theta = \sigma_1 > \sigma_r = \sigma_2 > \sigma_z = \sigma_3$، $\sigma_\Theta = \sigma_1 > \sigma_z = \sigma_2 > \sigma_r = \sigma_3 = 0$. Results showed that, in condition that tangential stress induced of lateral stress is maximum stress, shear failure occurred toward at around well. So, failure of wall of thick wall hollow cylinder is caused by the deviator stresses between lateral stress and inner pressure. By increasing deviator stresses, the plastic zone will increase around wall of thick walled hollow cylinder specimens. It is noteworthy that, presence of internal pressure reduces the breakouts propagation.

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1- Introduction

Well drilling in various industries such as oil, gas and mining industries is always associated with high costs and instability problems. Thus, it is vital to examine the behavior of wells during drilling process which usually is associated with the occurrence of various types of deformations and fractures [1, 2]. Hollow cylindrical specimens are used to investigate instability around underground spaces in various industries such as oil, gas and mining that have always been associated with high costs and many problems [3].

Experimental studies on the thick-walled cylindrical specimens date back to the twentieth century when Adams [4] and King [5] began laboratory studies on the hollow cylindrical specimens. Thereafter, Bridgman [6] repeated Adams works with changes in loading conditions. Robertson [7] studied the effect of inner diameter to outer diameter ratio on the strength and deformation of the hollow cylindrical specimens. Hoskins [8] conducted tests on hollow cylindrical specimens to determine fractures in five isotropic rocks. Alsayed [9, 10] studied the deformation behavior of hollow cylindrical specimens under different loading conditions.

Recently, Hashemi et al. [3] studied the effects of various parameters such as water and cement contents, grain size distribution, and the curing time of thick-walled cylindrical specimens to predict the stability of the wellbore during drilling. Using laboratory studies on thick-walled cylindrical specimens, Meier et al. [11] investigated the effect of the slope of layers on the stability of wellbores. In this regard, the fracture which occurred in the walls of thick-walled cylindrical specimens was examined by changing the slope of layers relative to the axis of the wellbore. Hashemi et al. [12] investigated the effect of various stress regimes on the wellbore stability by physical modeling of thick-walled cylindrical specimens. Their results showed the significant influence of confining pressure on the wellbore stability. Santana et al. [13] used a combination of laboratory studies on thick-walled cylindrical specimens and numerical methods to predict sand production in wellbores. Hashemi et al. [14] conducted laboratory studies on thick-walled cylindrical specimens made of low-strength cemented sand to investigate the relationship between the local zones and wellbore instability.

Studies on hollow cylindrical specimens indicate the importance and strengths of this approach. In this article, the efficiency of the triaxial cell designed for physical modeling of oil wells during drilling is examined through experiments on hollow cylindrical specimens of plaster and concrete under different triaxial loading conditions.

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2- The designed triaxial cell

The triaxial cell made by Hook and Franklin [15] is widely used for triaxial compression tests on solid cylinders with a diameter of 54.7 mm. Strain cannot be measured in this type of cell. But using the modified Hook cell designed by Hosseini et al., thick-walled hollow cylindrical specimens with a diameter of 73 mm can be tested for modeling oil well drilling as well as the modeling of hydraulic fracturing tests using this cell. A strain gauge can be installed on the wall of the central cavity to measure tangential strain.

3- Laboratory studies on plaster and concrete specimens

Hollow cylindrical specimens were made of plaster and concrete to simulate oil wells during drilling. A plaster to water mixing ratio of 3:1 was used to prepare the plaster specimens. The cement-sand ratio in concrete specimens was 1:1. According to the dimensions of the designed cell, the height, inner diameter and outer diameter of the prepared specimens were 156, 25 and 73 mm, respectively. To simulate the stress conditions before drilling, the pressure inside the well, confining pressure around the specimen and axial stress were increased with the same rate to reach the target values. To model the conditions during drilling, the pressure inside the well was reduced up to the fracture point at a constant confining pressure and axial stress. The pressure inside the well at the moment of failure represents the minimum pressure. In this case, $\sigma_\theta = \sigma_1 > \sigma_r = \sigma_2 > \sigma_z = \sigma_3$. Before applying stress conditions during drilling, experiments were carried out in the absence of internal pressure to obtain stress in the specimen prior to drilling. The pressure applied to the specimen before drilling should be higher than failure pressure in the absence of internal pressure under constant axial stress and variable confining pressure. In this case, $\sigma_\theta = \sigma_1 > \sigma_z = \sigma_2 > \sigma_r = \sigma_3 = 0$.

4- Conclusion

The following results were obtained from the tests:

- When $\sigma_\theta = \sigma_1 > \sigma_z = \sigma_2 > \sigma_r = \sigma_3 = 0$, shear failure occurs in plaster and concrete specimens in opposite directions of the drilled wellbore.
- When $\sigma_\theta = \sigma_1 > \sigma_r = \sigma_2 > \sigma_z = \sigma_3$, shear failure occurs again in the opposite directions of the drilled wellbore. However, the depths of failure differ in both cases such that the depth of failure is less in the case $\sigma_\theta = \sigma_1 > \sigma_r = \sigma_2 > \sigma_z = \sigma_3$ than in the case $\sigma_\theta = \sigma_1 > \sigma_z = \sigma_2 > \sigma_r = \sigma_3 = 0$.
- The ratio of horizontal stress to the vertical stress at the moment of failure in plaster and concrete specimens varies from 2.54 to 3.92 in both stress conditions.
- The failure of the wellbore wall in plaster and concrete specimens is due to the difference between the confining pressure and the internal pressure. By increasing this difference, the failure depth or plastic zone in the wellbore wall is increased.
- With increasing the difference between the confining pressure and internal pressure, the width of failure zone in the borehole wall increases.
- The depth and width of failure in the walls of thick-walled cylindrical specimens are dependent on the materials used in the preparation of thick-walled cylindrical specimens and are not the same for the plaster and concrete specimens.
- Given the applicability of the axial stress, confining pressure and internal pressure in the triaxial cell, different types of stress regimes (normal, reverse and strike-slip) and the effect of parameters such as geometric and mechanical properties of the thick-walled cylindrical specimens on the stability of walls can be investigated.

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