PROCEEDINGS
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Vertical Borehole Stability Analysis in Injection Well using Numerical Modelling

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Abstract

Vertical borehole stability analysis is one of the important aspects of wellbore monitoring in petroleum industry, especially in oil and gas production. In this paper, a wellbore which is going to be turned into an injection well as a part of EOR (Enhanced Oil Recovery) program will be modelled in a form of two-dimensional horizontal cross section of the well to help analyze the rock mechanics parameters as a part of the wellbore stability analysis. The horizontal cut must be in the area that includes shale and sandstone that has been determined mechanically. The model in this paper applied a numerical modelling method that is often used in geomechanical modelling for tunneling: Finite Element Method (FEM). At a depth of approximately 224 m, both strength factor and displacement around the borehole will be used to interpret the borehole stability. Besides modelling, a data log of the wellbore will be determined by using a simple estimation that shows some parameter curves to indicate the wellbore stability as well. Model results showed that the borehole is stable with strength factor ranged between 3.20-5.53.

Introduction

One of the reasons for a borehole to be instable is by disturbing the balance between its rock mass strength and the change of stress which caused induction stress that should be adjusted with the right mud pressure to stabilize the borehole. Another fluid injection inside the borehole also could cause an interaction between the formation and the fluid, which could increase the possibility of borehole instability. In this research, a borehole will be modelled by applying one of the numerical modelling methods: Finite Element Method (FEM) in 2D. The model will only be focused on a cased hole (casing and cementing) condition, of an injection well that locates in a developing oil and gas field in Field J, Well JD. Two approaches will be used in this model, such as using data log from the well relogging and rock mechanics test from the lab, to consider the possibility condition of the borehole from these two approaches is still stable and can be used for production. Results from both approaches will be compared and expected to be able to explain the borehole stability.

FEM was first applied to problems of stress analysis and has since been applied to other problems of continua (Cook, 1995). The modelling method is that it involves cutting a structure into several elements, describing the behavior of each element in a simple way, then reconnecting elements at "nodes" that hold elements together. This process results in a set of simultaneous algebraic equations. In stress analysis these equations are equilibrium equations of the nodes and the possibility of equations are very big, that computer implementation is mandatory.

FEM can be described as piecewise polynomial interpolation, which, over an element, a field quantity such as displacement is interpolated from values of the field quantity at nodes and becomes interpolated over the entire structure, by as many polynomial expressions as there are elements. The "best" values of the field quantity at nodes are those that minimize some function such as total energy. The minimization process generates a set of simultaneous algebraic equations for values of the field quantity at nodes. Matrix symbolism for this set of equations is $[K]\{u\} = \{F\}$, where $[K]$ is stiffness matrix, $\{u\}$ is nodal displacements of unknown, and $\{F\}$ is known nodal forces. The unknown nodal displacements can be calculated using the help of Phase 2 software. Phase 2 is a part of Rocscience that used 2D elastoplastic analysis with finite element stress analysis of underground excavation or surface for both rock and soil.

Data and Method

The data came from the Field J. Well JD was picked as the borehole for research because it has both rock mechanical properties and data log. Data log was used to determine the distribution at every depth and identify the lithology aspects of the well. The results of data log calculation, such as overburden stress, minimum horizontal stress, maximum horizontal stress, pore pressure, mud weight, and hydrostatic pressure, will be used for data log analysis and the calculated in situ stress from it will be applied into the numerical modelling.

A model with the help of Phase 2 will be made by applying the general method of tunneling model, which is by using liner parameter and reinforced concrete for the casing and cementing respectively, that are both provided in Phase 2. The 2D FEM geometry model will be created as a horizontal cross section of the borehole. This cross section was picked in depth that contained sandstones and shale, which allegedly have a good potential of hydrocarbon sealing. The borehole diameter with circular opening of the depth between 200 m to 500 m is 8.5 in or 0.2 m. Boundary width is 5R or more (0.6 m) with boundary condition is zero velocity on left-right and upper-lower model.

The model casing was made by using liner parameter that is usually used within tunnel modelling such as standard beam and reinforced concrete parameters. Input parameters such as rock mechanics and in situ stress were calculated from lab test and data log calculation, respectively.

Result and Discussion

Results showed that a horizontal crosscut of the borehole has the strength factor between 3.20 to 5.53 in the depth of 224 m. This strength factor has a minimum at point C (based on the point legend of Figure 2) that is in the same direction as the direction of maximum horizontal stress (or S_{Hmax}); indicates that shear failure did happened around the borehole that is in the same direction as S_{Hmax} direction. This results also showed that the borehole is still stable after the casing and cementing process. Besides strength factor, total displacement of the borehole is also being estimated to see how big the displacement could happen around the borehole after the casing and cementing process. Results showed that total displacement of Well JD in depth 224 m is around 0.013 mm to 0.051 mm, with direction dominantly moved parallel along with S_{Hmax} direction.

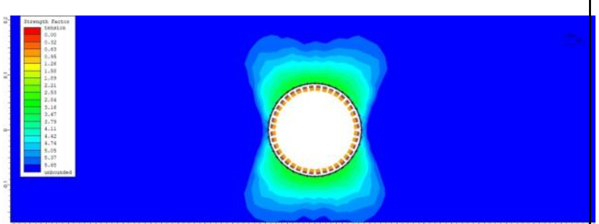

Figure 1: Strength factor of Well JD in 224 m depth.

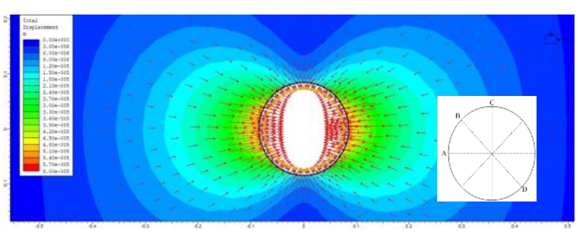

Figure 2: Total displacement of Well JD in 224 m depth.

The borehole stability model could also be estimated by using simple estimation of the data log of Well JD. Data log was obtained from the results of well relogging and could be used as a part of validation and/or borehole monitoring. Based on Figure 3, all curves show the ideal condition of a wellbore. Data log was estimated using calculation based on Zoback, 2007; with plotting only shale and using the strike-slip fault regime approach for the borehole, which results in a condition where S_{Hmax} curve will be greater than overburden gradient (or OBG) curve and minimum horizontal stress (or S_{hmin}) curve will be smaller than OBG curve.

Mud weight was estimated to see if the curve is still between pore pressure and fracture gradient (S_{hmin}) curves. Mud weight curve that is too close with S_{hmin} curve could increase the risk of greater facture and mud loss, while if it is too close with pore pressure curve, the possibility of blowout would increase as well as borehole instability risk. Mud weight curve that is over the pore pressure curve also indicates overpressure and increasing the risk of borehole instability as well. Overpressure usually happens in the depth 500 m or more, therefore mud weight curve should be kept in between pore pressure and fracture gradient curves to prevent such cases.

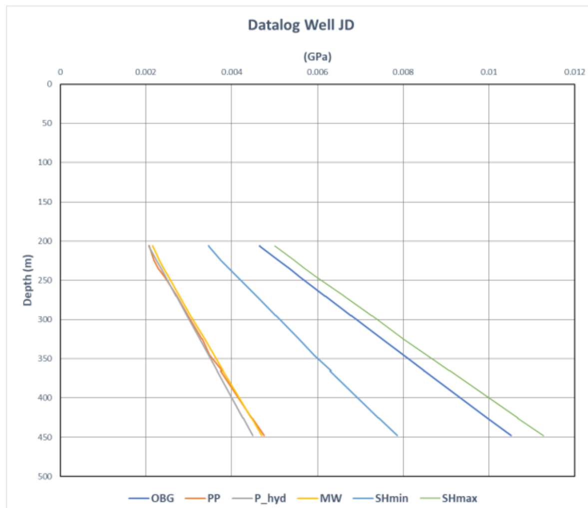

Figure 3: Simple estimation results of data log Well JD.

Although simple estimation results showed the borehole is still in a stable condition, there should be a numerical estimation to help obtain a more specific result than simple estimation could do before. Previous research has already used data log estimation using Drillworks Predict to read the same data log as this research and showed that borehole is still in a stable condition as well.

Conclusions

From this research, we can conclude that the model and data log results show that Well JD is still in a stable condition in terms of strength factor and total displacement around the borehole. Maximum displacement happened in the borehole area that is in the same direction as maximum horizontal stress, which mean the deformation will move alongside minimum horizontal stress direction.

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