Aerated Drilling Optimization in Geothermal Well Drilling in Field “X” Cluster “Y”

(Optimasi Pemboran Busa Pada Pemboran Sumur Panasbumi Di Lapangan “X” Cluster “Y”)

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Abstract
Aiming for productive fault in Suban Agung Rim, Field X Cluster Y Bengkulu Province, Indonesia, PT Pertamina Geothermal Energy (PGE) drilled some wells to discover the potential awaited. However there are challenge awaits each meter ahead especially in reservoir sections where loss circulation is expected. Knowing the risk, PGE decided to drill the well utilizing aerated drilling. The method has known for decades to be the most effective approach in dealing loss circulation. The method applies certain value of compressed air to be injected in fluid stream, so bubbling process can be achieved in order to reduce the mud weight. The method has benefit to maintain ROP and minimize the risk for pipe get stuck due to poor hole cleaning in fractured formation. There are three wells drilled in Field X Cluster Y which has the same problem in 9-7/8” section; all experienced stuck pipe while drilling. During the process aerated drilling was utilized, however it was not sufficient. This paper will discuss and explain on how the occurrence happened and what to do next in similar condition to avoid the problems.

Keywords: Drilling, ECD, Geothermal, Hole Cleaning, Loss circulation

I. INTRODUCTION
In general there are similarities between oil and geothermal wells in term of drilling, both the equipment and the method. There are three main parameters to drill a well namely weight on bit, rotation, and circulation. The circulation system plays important role to wash and displace the cuttings away from the drill string so the depth increment can be accomplished to target depth. The combination of each aspect will result in the rate of penetration (ROP).

ROP is a value to define the depth by the time needed. If the value goes high and no problems occurred, it can be tell that the drilling progress is excellent. To achieve such condition is not by setting ROP as fast as possible, but to achieve the optimum rate. Since the speed is determined by how much cuttings produced by the bit grinding the formation and displaced effectively by the drilling fluid. If the ROP is too high but the drilling fluid cannot keep up to clean the hole, then problems may occur, such as high torque and then stuck pipe.

Optimum ROP can be achieved if the synergy between cutting generation and displacement is inline. The displacement is provided by certain volume of mud which is pumped in a certain time to accommodate the ROP. The pumping rate must be able to push the cuttings up in a condition where the cuttings have a tendency to drop due to gravity force across the trajectory. The pumping rate is defined by the minimum velocity required to handle the slip velocity of the cuttings.

II. METHODOLOGY
The successfulness of aerated drilling appliance is
based on how much drilling fluid volume needed to fill the annulus as well the annular velocity as per pumping rate function. All is needed to keep the hole filled and cuttings displaced properly. However in the presence of productive fractured that may result on fluid loss to formation; will reduce the performance of drilling fluid in carrying cuttings. The occurrence happened due to fluid will have tendency to flow into the fractures instead of surface. The method to be applied in order to mitigate the circumstance is by reducing the fluid density, low enough to get near balanced condition. The purpose of the method is to keep sufficient amount of fluid volume in the hole to sustain the cuttings and displace it properly. Stated in following formula is the explanation on how ROP is defined.

\[
C_a = \frac{\text{ROP} \cdot \sigma_{\text{p}}}{60 \cdot (v_a - v_s) \cdot (d_h^2 - d_p^2)} \quad \ldots \ldots \ldots \ldots \ldots \ldots (1)
\]

Where \( C_a \) (cuttings annular concentration) is the function of ROP, \( D_h \) (hole diameter), \( v_a \) (annular velocity, 140 fpm minimum), \( v_s \) (slip velocity), and \( D_p \) (outside diameter of pipe). But above all the most important aspect is to maintain the kinetic energy of the fluid to be above 2 lb-ft/ft^3 (Guo et.al, 2002).

The research started with gathering data that essential for the simulation process. The main data entails vertical depth (TVD) and measured depth (TMD). Furthermore supporting data such as hole size, inclination (trajectory), trajectory length, and many more. Geological data is also essential in defining what will be best decision to be decided in certain type of formation.

After all data gathered, analysis started by the quick look, where to discover which part can be taken as basis of optimization, where the expected result is defined here. Hence the modeling for the aerated drilling can represent the actual condition being encountered, not only engineering wise but also able to be implemented operational wise.

Modeling is done for some wells that chosen to be research target. The candidate wells must have identical or at minimum similar character in order to get the certain trend in both designing and executing a drilling program. Hence the models will be analyzed and correlated to be final design and result.

Nevertheless in reality geothermal wells have significant character with oil wells, such as scattered fractures that will show different behavior in neighboring wells.

After the modeling is finish, then the modeling will be proposed to be recommendation that can be applied with adding operational aspect. This can be used as guide line to point the starting value of how much air is required in the operation and dynamically changed if necessary.

From the research, it is expected to give result in form of recommendation for parameter that suitable in real time operation. The result will be delivered in operating envelope that will be designed in each section with limitations. The limitations are annular velocity and maximum reservoir pressure.

![Figure 1. Scheme for Working Envelope of Aerated Drilling](image)

Figure 1 shows the scheme for working envelope of aerated drilling. As indicated in the figure, the conditions of various mud rate in air injection rate will result various values of BHCP (bottom hole circulating pressure), that suitable for each conditions. suitable for each conditions.

### III. RESULTS AND DISCUSSION

There are three wells to be taken as research data, which drilled next to each other in the same cluster. Those wells encountered problems especially in 9-7/8” section, where in the last well of Y-3 was decided to be abandoned due to unrecoverable fish on bottom. The fish was occurred when drilling started from 2400 mMD to 2580 mMD. Besides, the neighboring wells, Y-1 and Y-2, also encountered stuck pipe that consume significant amount of time to get freed.

Started from well Y-1 that had stuck pipe while drilling with 9-7/8” section. The stuck pipe was occurred while attempting to pull out of hole from last depth of the hole on 2722 mMD. During the time, there was no fluid return to surface due to previously total loss encountered. From the report, it is known that the aerated appliance was still far from optimum. Known from the calculation that the ECD was too high in range of 6.7-7.8 ppg. This is showing poor result and risky to be implemented as well, where the targeted ECD is in 6 ppg. Hence the recommendation to be implemented is using 500-600 gpm and 1300-1700 scfm. The range also showing sufficient hole cleaning requirements.
Next is the stuck pipe occurred while drilling well Y-2 section 9-7/8”, where the occurrence happened twice at 2208 mMD while pulling out of hole from 2208 mMD and 2356 mMD. During the time, there was no fluid return to surface due to previously total loss encountered. From the report, it is known that the aerated appliance was still far from optimum. Known from the calculation that the ECD was too high in range of 6.7-7.6 ppg. This is showing poor result and risky to be implemented as well, where the targeted ECD is in 6 ppg. Hence the recommendation to be implemented is using 500-600 gpm and 1200-1700 scfm. The range also showing sufficient hole cleaning requirements. The stuck pipe occurred due to significant fluid loss to formation, hence the hole cleaning was insufficient. To free the pipe, air was pumped 2200 scfm and mud 600-950 gpm, and pipe was successfully freed.

Next is well Y-3 that also experienced stuck pipe at 9-7/8” with fish left in hole. Stuck was occurred at 180 mMD below casing shoe which previously drilled from 10-3/4” casing shoe. Known from the calculation that the ECD was too high in range of 6.3-7.3 ppg. This is showing poor result and risky to be implemented as well, where the targeted ECD is in 6 ppg. Hence the recommendation to be implemented is using 500-600 gpm and 1300-1600 scfm. The range also showing sufficient hole cleaning requirements.

However with the pipe freed with air doesn’t mean that the operation is considered smoothly done. The main idea is to avoid such circumstance. As following is the model that visualize the actual and proposed recommendation.
IV. CONCLUSIONS AND RECOMMENDATION

Berdasarkan hasil analisa data dan perhitungan uji sumur yang dilakukan pada sumur gas X-1, maka dapat disimpulkan sebagai berikut:

1. Aerated drilling appliance not yet optimum due to excessive mud rate. From all wells, it is known in average that the ECD is in 7 ppg which still too high from the reference of 5-6 ppg.

2. The concept of kinetic energy takes it’s role instead of yield point in carrying cuttings, where the presence of gas in the system cannot be calculated conservatively. The minimum annular velocity that applies also need to be inline with kinetic energy (minimum 2 lbf-ft/ft3) with minimum value of 140 fpm.

3. The injection rate for air and mud must be in optimum, according to the calculation, which in each increment of mud rate will increase the ECD, so the concept of optimum aerated drilling is minimum liquid with optimum air rate.

4. Operating envelope that designed only for certain condition and need to be updated in each changed made for various parameters.

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