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Application of Underbalanced Drilling Using the Guo-Ghalambor Method Approach in Lahendong Geothermal Field, Sulawesi Utara

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Abstract:- Sometimes a drilling operation in a geothermal field needs to be evaluated for the purpose of oprimizing the drilling itself. Therefore, it is necessary to carry out qualitative calculations to analyze whether the drilling operation is running optimally or not. The aim of using aerated drilling is to reduce zones with low pressure in the formation which could potentially cause lost circulation. The main purpose of using this method is to lift the cutting towards the well's surface. The parameters considered in aerated drilling include well bottom pressure, drill cutting removal and well geometry. So by using this data, Liquid-Gas Rate Window boundaries are formed which will later be used as a reference for determining the optimal gas flow rate for cutting removal. The Kick Off Point (KOP) starts at a depth of 497 m-MD with a maximum inclination of 30° and a total depth of 1974 m-MD. The geothermal well has the following casing configuration: 30" casing, 20" casing. 13-3$^3/_8$" casing, 10-$^3/_4$" casing, 10-$^3/_4$" liner dan 8-$^5/_8$" liner.

Keywords: *Underbalanced Drilling, Lost Circulation, Geothermal.*

1. Introduction

The scientific journal entitled Application of Underbalanced Drilling Operations in Geothermal Field well in the Lahendong Area aims to evaluate the aerated drilling method carried out on a 12 1⁄4 " route. This drilling operations carried out in 46 days. The data that the writer used in this paper include well pressure, well temperature, cuttings density, rate of penetration, collapse pressuse, drill cuttings diameter, mud weight and specific gravity. Calculations from those data can be used to determina the values of Ciculation Break Bottom Hole (BHP), Flowing Bottom Hole Pressure and Air Injection Rate. The parameters used in aerated drilling operations are then compared against the reference. The difference between actual and reference will be evaluated, then optimization will be carried out to find out which is more optimal qualitatively for lifting drilling cuttings to the surface. Evaluation of this parameter uses the trial and error method by estimating how large the gas injection rate will be in a flowing or static well. The success of well drilling is a key factor in the development of geothermal fields. Aerated drilling is an underbalanced drilling technique aimed at improving well production. To overcome hole problems such as stuck pipes due to accumulation of cuttings that occur to non-optimal cutting removal in geothermal fields, the aerated drilling method is used. Apart from optimizing the lifting of drill cuttings to the surface, this is also to reduce the occurrence of downhole problems which can disrupt drilling operations in terms of cost and time. Writer hoping that after carrying it aeration drilling is to address drilling problems and reservoir zone damage that may occur in a drilling environment if overbalanced drilling is used. By mixing the gas phase in the drilling mud, there are possible side effects in this operation. However, in some cases and well formation conditions, underbalanced drilling can be the best option because using mud with a lower pressure than the formation pressure can reduce the occurrence of lost circulation. On the other hand, drilling mud can still lift cuttings from the well to the surface optimally. Therefore, it is necessary to carry out calculations to determine the density of drilling mud that is suitable for uses in aerated drilling operations. The advantages of using aerated drilling include increasing the rate of penetration, overcoming lost circulation problem and maintaining the condition od the formation from damage due to drilling. The drawback is that it requires additional tools for drilling operations, increasing the risk of kicks and corrosion easily happened due to the use of gas phase in aerated drilling. Analysis of production wells is carried our by creating several liquid-gas rate window limits from calculations of collapse pressure limit, balance pressure limit, cutting carrying capacity, and wellbore washout limit.

2. Objectives

The aeration drilling tools consist of separator, compressor, booster, mist pump, blooie line, rotating head and string float valve. Each of them has to be chosen carefully to suit the geothermal well which is being researched.

3. Methods

According to Guo Ghalambor's reference, aerated drilling mud is mud that provides and underbalance condition consisting of a gas phase and a liquid phase. The density of aerated sludge is between 3-7 Pounds Per Gallon (ppg). The gas phase injected into the base mud functions to reduce the density of the base mud used.

$$A = \frac{\pi}{4}(\phi h^2 - \phi dp^2) \tag{1}$$

$$\bar{e} = \frac{0.004167x\phi h^2 + 0.00015x\phi dp^2}{\phi h^2 + \phi dp^2} \tag{2}$$

$$f = F\ LHU\left[\frac{1}{1.74 - 2\log\left(\frac{2\bar{e}}{DH}\right)}\right]^2 \tag{3}$$

$$a = \frac{0.00014db^2SsROP + 0.25WmQm + 144SlQfx + 0.19SgQgo}{TQgo}\cos(\Theta) \tag{4}$$

$$b = \frac{0.033Qm + 0.023Qfx}{TQgo} \tag{5}$$

$$c = \frac{9.77TQgo}{A} \tag{6}$$

$$d = \frac{0.33Qm + 0.023Qfx}{A} \tag{7}$$

$$e = \frac{f}{2gDHcos(\Theta)} \tag{8}$$

Vertical section

$$b''(\mathrm{Phy} - \mathrm{Ps}) + \ln\left(\frac{Phy}{Ps}\right) = a''H \tag{9}$$

Angle Build Up Section

$$b(\mathrm{Phy}\text{-}\mathrm{Ps}) + \ln\left(\frac{\mathrm{Phy}}{\mathrm{Ps}}\right) = \mathrm{a}Rsin(Im) \tag{10}$$

Slant Section

$$b(\mathrm{Phy}\text{-}\mathrm{Ps}) + \ln\left(\frac{\mathrm{Phy}}{\mathrm{Ps}}\right) = \mathrm{a}Scos(Im) \tag{11}$$

For the Liquid-Gas Rate Window calculations, we will do calculate for every boundaries such as Collapse Pressure, Balanced Pressure, and Cutting Carrying Capacity.

Collapse Pressure Calculation

$$A = \frac{\pi}{4}(\phi h^2 - \phi dp^2) \quad (12)$$

$$b"(Phy - Ps) + \ln\left(\frac{Phy}{Ps}\right) = a"H \quad (13)$$

$$b(\text{Phy-Ps})+\ln\left(\frac{\text{Phy}}{\text{Ps}}\right)=\text{a}Rsin(Im) \quad (14)$$

$$b(\text{Phy-Ps})+\ln\left(\frac{\text{Phy}}{\text{Ps}}\right)=\text{a}Scos(Im) \quad (15)$$

Balanced Pressure Limit Calculations

$$b''(\text{Pfr1-Ps})+\ln\left(\frac{\text{Pfr1}}{\text{Ps}}\right)=\text{a}"d"^2e"H \quad (16)$$

$$b"(\text{Pfr1-Ps})+\ln\left(\frac{\text{Pfr1}}{\text{Ps}}\right)=\text{a}"d^2\text{e}RIm \quad (17)$$

$$b"(\text{Pfr1-Ps})+\ln\left(\frac{\text{Pfr1}}{\text{Ps}}\right)=\text{a}"d^2\text{e}"S \quad (18)$$

Cutting Carrying Capacity Limit Calculations

$$A = \frac{\pi}{4}(\phi h^2 - \phi dp^2) \quad (19)$$

$$V_m = \frac{P_{hy}}{c"} + d" \quad (20)$$

$$Vtr = \frac{\pi db^2}{4CpA}\left(\frac{Rp}{3600}\right) \quad (21)$$

$$Vsl = 5.35\sqrt{\frac{Ds(\rho s - \rho f)}{\rho}} \quad (22)$$

4. Results

The aerated drilling parameters that influence the lifting of cuttings in the drill hole in the total loss zone are the circulation fluid velocity in the annulus, the critical velocity of the drill cuttings, the terminal velocity of the drill cuttings, the density of the circulation fluid and the viscosity of the circulating fluid. The well that has been studied had water influx conditions and did not have dissolved gas conditions, so after conducting a qualitative study it was estimated that it would be better if aeration fluid was used because it is more stable and more suitable compared to other drilling fluids. To carry out data calculations, primary data that has been taken previously is in the form of formation pressure, collapse pressure, surface temperature, choke pressure, drill cuttings diameter, drill cuttings density, mud weight, influx specific gravity, influx flow rate , gas specific gravity, casing diameter, bit diameter, outer diameter of drill pipe, pipe roughness, hole roughness, maximum inclination and rate of penetration. The value of the relationship between mud flow rate and gas injection flow rate is obtained from previous calculations which will later form an intersection point which can be seen in Table 1 below.

Table 1: Circulation Break Bottom Hole Pressure

Qgo	Qm (gpm)
3000	300
3500	400
4000	500
5000	600
6000	700
7000	800
8000	900

Then for calculating the left limit, we still more or less use the formula that was listed previously. The BHP value during this dynamic condition will be influenced by the diameter of the annulus hole. With the difference in diameter of the Bottom Hole Assembly, calculations need to be carried out in detail and very carefully.

Table 2: Intersection value at Flowing Bottom Pressure

Qgo	Qm (gpm)
2200	300
2800	400
3150	500
4150	600
4500	700
5500	800

Next, is the calculation of Cutting Carrying Capacity or the lower limit of the Liquid-Gas Rate Window. It is known that it takes a kinetic energy of 3 ft-lb/ft^3 to be able to lift cuttings from the borrom of the drilled well to the surface. The author has calculated the kinetic energy for each pump flow rate with the values in Table 3 below.

Table 3: Kinetic Energy Value at each mud pump flow rate

Qgo (scfm)	Qm (gpm)	Em (ft-lb/ft³)
2000	300	3,719
2650	400	6,179
3000	500	9,046
3600	600	12,745
4300	700	17,106
5100	800	22,182
6000	900	28,162

From the data above, it can be concluded that by using varied mud flow speedsm the kinetic energy produced is above the value of 3 ft-lb/ft³, whoch means that cuttings can be lifted to the surface optimally. The final step to create an LGRW graph is to determine the Wellbore Washout Limit or lower limit. This lower limit line is defined as the maximum condition for aeration drilling before washout occurs in the well. To determine this limit, considering that aerated drilling operations are carried out in geothermal fields which are not relevant to washout events, the author uses the 8" mud motor standard as a areference.

When all the limits combined in one graph, the LGRW boundaries will form a 2D window as in the following image. Drilling operations are expected to continue within this window. If the drilling operation is not within the formed window, drilling problems will occur.

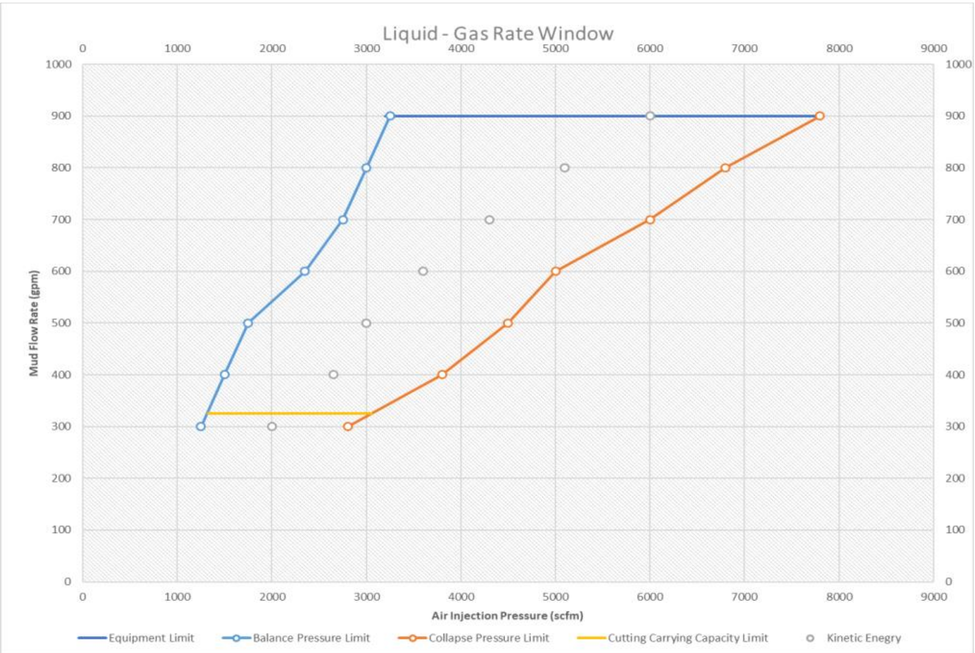

Figure 1: Liquid-Gas Rate Window graphic with a mud 8.5 ppg on route 12.25" in Lahendong Geothermal Field

5. Discussion

Based on the calculation results of the aerated drilling application method Lahendong geothermal area, the following conclusions can be about five, it is the parameter values resulting from the aerated drilling evaluation at the right boundary obtained the quantities Qm and Qgo, where at a mud pump rate of 300 gpm a Qgo was obtained of 3000, a mud pump rate of 400 gpm obtained a Qgo value of 3500, a mud pump rate of 500 gpm obtained a Qgo value of 4000, a mud pump rate of 600 gpm obtained a Qgo value of 5000, a mud pump rate of 700 gpm a Qgo value of 6000, a mud pump rate of 800 gpm a Qgo value of 7000 was obtained and a mud pump rate of 900 gpm was obtained Qgo value 8000, the intersection value of Flowing Bottom Pressure at each pump flow rate is 2200, 2800, 3150, 4150, 4500 and 5500. The cutting carrying capacity limit or lower limit value of the LGRW graph after calculation is at a 300 gpm mud flow rate of 3,719 ft-lb/ft^3, a 300 gpm mud flow rate of 6,179 ft-lb/ft^3, a 500 gpm flow rate of 9,046 ftlb/ft^3, a 600 gpm flow rate is 12,745 ft-lb/ft^3, 700 gpm flow rate is 17,106 ft-lb/ft^3, a 800 gpm flow rate is 22,182 ft-lb/ft^3, a900 gpm flow rate is 28,162 ft-lb.ft^3. From the graph that has been created, it is possible to determine the water gas pressure flow rate freely as long as it remains within the limits that have been created. The parameters that must be considered when calculating the application of aerated drilling are the mud pump pressure and the mud discharge.

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