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Sensitivity Analysis of Geothermal Drilling Parameters - A Case Study of Well MW-17 in Menengai Kenya

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ABSTRACT

Rate of penetration (ROP) is one of the most important factors that determines the success or failure of a drilling project. Very low rates of penetration implies that the overall time it will take to complete drilling a well will be very long and vice versa. Time has a direct bearing on the cost of drilling. Long time taken to drill a well may lead to cost overruns and hence failure to successfully complete the drilling project. It is therefore very important to control the ROP in such a way that drilling will be done within the planned timelines and hence cost.

There are several factors that affect the rate of penetration when drilling geothermal wells. These factors were looked at in great detail in my previous paper entitled 'Modelling of Geothermal Drilling parameters- a case study of well MW-17 in Menengai Kenya'. The parameters that affect ROP are: Formation strength, Formation depth, Formation compaction, Pressure differential across the hole bottom, Bit diameter and weight on bit, Rotary speed, Bit wear, Bit hydraulics. Of these parameters, the driller can very easily control the Rotary speed (Rotations per minute-RPM) and the Weight on bit (WOB). These parameters have a direct relationship with ROP. Increasing them will lead to increase in ROP. This is the reason why these parameters were considered in this paper; to see the extent to which they affect the ROP when they are increased or decreased by a certain percentage. This paper is a continuation of my previous paper: 'Modelling of Geothermal Drilling parameters- a case study of well MW-17 in Menengai Kenya'. It uses the modelled parameters (WOB and RPM) to check their sensitivity to ROP.

1. INTRODUCTION

Menengai is one of the high temperature geothermal fields found within the Kenya Rift Valley. The Kenya rift is part of the Eastern arm of the East African Rift System. The litho-stratigraphic successions in the Menengai geothermal field are predominantly trachytes. Other rock types found include pyrochlastics, tuff, syenite and basalt. (Kipchumba, 2013). Exploration Drilling in Menengai geothermal field started in 2011 with drilling of well MW-1. By May 2017 Over 60 geothermal wells had been drilled in Menengai field. Drilling is ongoing with 7 2000HP rigs.

Data for well MW-17 from Menengai field in Kenya is used for this case study. The well was drilled in 2013 to a depth of 2218 m in 121 days. Drilling of wells in Menengai geothermal field in Kenya takes longer to complete than usual. This is because of challenges encountered when drilling through different sections of the well. The surface section is characterised by hard and abrasive formations which cause excessive vibrations of the drillstring when high rotation speeds and weight on bit are applied. The Intermediate hole is characterised by hard formations and loss of circulation. The production hole has good drillability but frequent loss of circulation and the drillstring getting stuck are common. One possible solution to these challenges is to apply the right drilling parameters.

The parameters such as WOB and RPM and pumping rate are easily controlled by the operator and if rightly applied, they can improve the drilling performance greatly. Of these three easily controllable parameters, WOB and RPM were used in the sensitivity analysis. Pumping rate will be considered in future studies.

2. SENSITIVITY ANALYSIS

The easily controllable parameters; WOB and RPM, were used to test the sensitivity on the ROP penetration by increasing and decreasing the parameters, one at a time, by 30% while holding the other parameters constant. The figures 3 to 8 below show the result of the sensitivity analysis. The sensitivity of ROP to changes in WOB and RPM was done by increasing and decreasing the WOB and RPM by 30% and the results are as discussed below

Normally it is expected that ROP and RPM have a direct relation and thus increasing RPM should lead to an increase in ROP. Bourgoyne et al., 1991 stated that penetration rate increases linearly with rotary speed at low values of rotary speed as shown in figure 1 below. The effect diminishes at higher rotary speed due to ineffective hole cleaning.

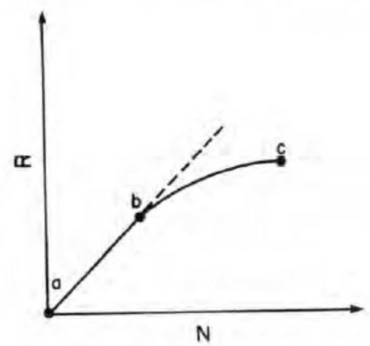

Figure 1 Rate of penetration (R) versus rotary speed (N) (Bourgoyne et al., 1991)

In the same way increasing weight on bit is expected to lead to increase in rate of penetration as shown in figure 2 below. The relationship between ROP and WOB holding all other factors constant is as shown in Figure 2. There is no significant ROP realized until the threshold WOB is applied shown by point a. After applying the threshold WOB, there is rapid increase in ROP with moderate increase in WOB (section ab). A linear relationship between the ROP and WOB is observed for moderate WOB (section bc) and at higher values of WOB, subsequent increase in WOB only results in slight increase in ROP (section cd). In some cases, a decrease in ROP is observed at extremely high values of WOB as seen in section de. This behaviour is called bit floundering and is attributed to poor hole cleaning at the bottom of the hole due to high generation of cuttings (Bourgoyne et al., 1991)

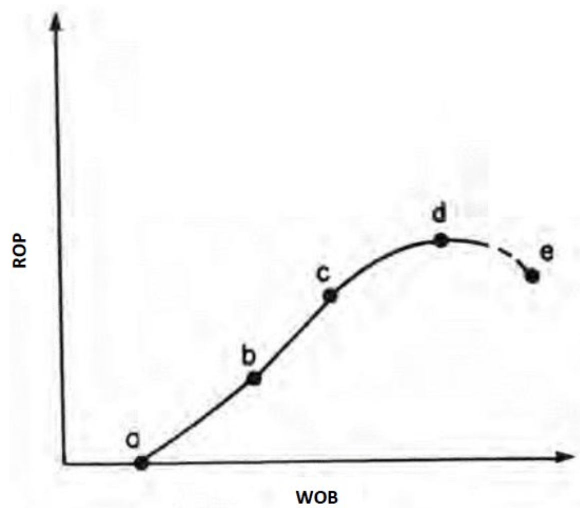

Figure 2 ROP versus WOB, (Bourgoyne et al., 1991)

2.1 Sensitivity analysis for Surface Hole

By increasing the RPM by 30%, the model unexpectedly responded by a decrease in ROP. This is an abnormal response that may have been picked by the model as a result of applications of drilling parameters by the operator in a way that is not consistent.

In Figure 3 increase in rotary speed leads to a decrease in ROP. Analysis of the data showed a negative correlation of -0.27 between the RPM and ROP for this section. The drilling history recorded excessive vibration when increasing WOB and RPM to the point that it was impossible to make advances in depth hence decrease in ROP (Menengai well completion reports). This may have forced the operator to apply low RPM that led to Increase in ROP.

Increasing or decreasing WOB did not have an effect on ROP. This was because the weight on bit (WOB) used was so low that it didn't reach the threshold value for the model to respond in changing the ROP. Thus RPM had a greater effect on ROP than WOB for the surface section.

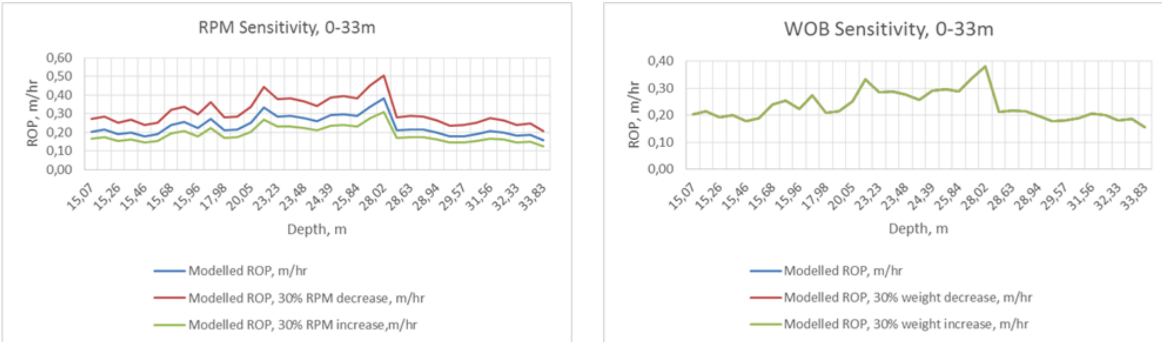

Figure 3 Sensitivity of ROP on WOB and RPM for the surface hole

2.2 Sensitivity analysis for Intermediate Hole

In this section, increasing RPM led to a direct increase in ROP. Decreasing RPM on the other hand led to a direct decrease in ROP as seen in Figure 4. Changing WOB had little effect on ROP. This is because the WOB used was close to the threshold weight and in some cases below the threshold weight.

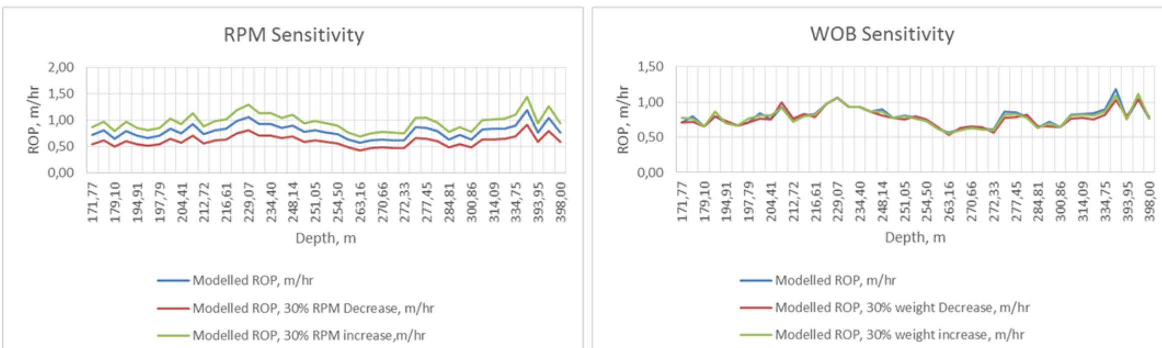

Figure 4 Sensitivity of ROP on WOB and RPM for the Intermediate hole

2.3 Sensitivity analysis for Production hole

In this section (684-772m), as seen in Figure 5, there is an indirect relationship between RPM, WOB and ROP. The ROP is very sensitive to changes in RPM. The data collected shows that the correlation between RPM and ROP is -0.4. The drilling history shows there was a fault with the torque sensor and the operator applied RPM and WOB reservedly when drilling this section (MW-17 Well Completion report, 2013). This section is composed of Tuff which is very soft and reducing WOB and RPM from previous high values still leads to an increase in ROP.

In section 772-1010m (Figure 6), there is a direct relationship between RPM and ROP. Change in WOB had insignificant effect on the ROP this is because the weight applied was mostly below the threshold weight.

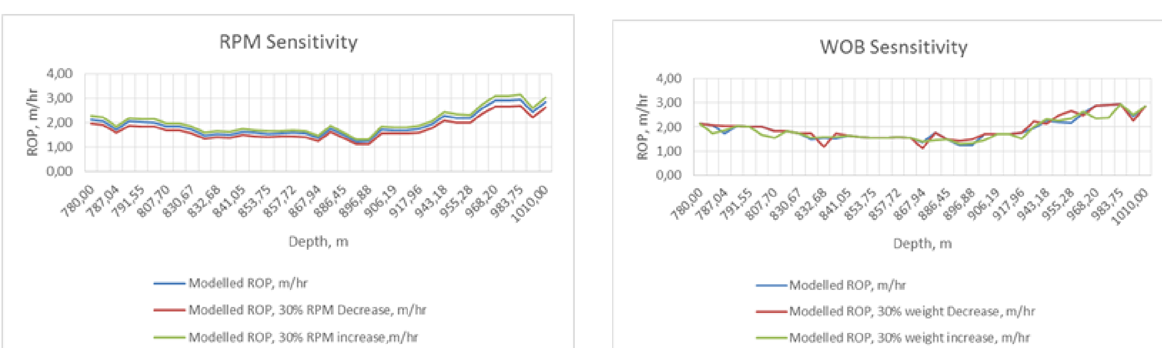

Figure 6 Sensitivity of ROP on WOB and RPM for the production hole

Open Hole

The section 1375-1410m, shows increasing WOB and RPM leading to a direct increase in ROP with RPM having a greater effect on the ROP than WOB. In section 1410-1970, change in RPM leads to a direct change in ROP. A change in WOB leads to an indirect change in ROP. The correlation between measured WOB and measured ROP for this section is negative hence the model picked the indirect relationship. This is because of the operator's application of parameters in a controlled manner since this section of the hole is prone to stuck drill string.

Figure 7 Sensitivity of ROP on WOB and RPM for the open hole

Figure 8 Sensitivity of ROP on WOB and RPM for the open hole

3. DISCUSSION

From the sensitivity analysis, it could not be clearly pointed out which of the two parameters (WOB and RPM) had a bigger effect on the ROP. This really depended on the section of the well being drilled. This may have been as a result of the unique application of the drilling parameters in a controlled manner due to the conditions that prevailed while drilling. For instance it was not possible to increase WOB on the surface hole due to excessive vibration and the driller utilized more the RPM to advance drilling. The same case can be seen in other sections of the well. The other reason may have been because of the formation that was not consistent hence constant parameters could not be applied continuously. This is very different when it comes to the oil fields which have homogeneous formations in most sections of the wellbore.

4. RECOMMENDATIONS

This study shows that the WOB and RPM didn't have a great sensitivity on the ROP. Analysis of the data showed that WOB was most of the times below the threshold. The WOB should always be above the threshold value in order to have enough force to shear off the rock. Only if this is done can we have a significant effect on ROP by increasing WOB and RPM

5. CONCLUSION

This study shows that the effects of WOB and RPM on ROP are closely related. If the WOB is below the threshold value, increasing the WOB and RPM will not have a significant effect on ROP. Most of the time the driller did not apply the right amount of the WOB hence low ROP. Sufficient WOB needs to be applied above the threshold weight only then can the sensitivity of the parameters be picked by the model.

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