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Torque and Drag Sensitivity Analysis for Geothermal Deep Well

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ABSTRACT

In the early phase of well planning design, several aspects are taken into account in order to reach the target depth. One of the aspect that mostly disrupt the achievement into the target depth is the excessive torque and drag suffered by the drill string and BHA along the way to the surface. It is essential for understanding the factors that affect the torque and drag number, hence it can be used for better well planning and prevent the risk of potential drilling problems. The main factor that will be analyze in this paper is the effect of various hole geometry design into the calculation models of dynamic torque and drag. The calculation models of torque and drag are mostly describes the mechanical forces which is consist of frictional losses to rotate and force to raise and lower the BHA and drill string. By putting a different variable of trajectory design such as kick-off depth, build up rate and final well inclination to reach the similar target depth, the optimal torque and drag roadmaps could be estimated and the best scenario of the hole geometry for geothermal deep well will be obtained.

1. INTRODUCTION

Nowadays, the exploration of geothermal energy resources in Indonesia were limited by geological targets located in deep formation zone. The objective to reach the long and deep well target is not easily achieved, due to several aspects that can interfere during the drilling operation. One of the aspects that needs to be consider in the early phase of well planning is the possibility of having the excessive torque and drag occurred in the drill string and BHA. It is important to identify the factors that determined the calculation of torque and drag, besides the risk of potential drilling operation problem that goes with it.

This paper will describe the process of simulating the dynamic torque and drag analysis and its correlation with various hole geometry design as the main factor. The purpose of this simulation is to look for the influence of determining the depth of the kick-off point as a direct relationship between hole geometry design and torque and drag analysis calculations. Based on the simulation result, it is expected that we can define the optimum geometry hole design that is in accordance with the trajectory that we have planned. This simulation study then were compared with the actual data from two wells in PGE development field, which has been drilled and reflects the case that similar with the simulation process.

2. WELL DESIGN AND SIMULATION

The process was started with forming a typical well design for deep well with total measured depth of 3200 m. the software used for running the simulation process is COMPASS and WELLPLAN from Landmark™. Prior to simulation of torque and drag, it is started with build a directional well by putting some assumption number needed to complete the well design. The well is a slant type model (J-Type) with the various number of design parameter. According to the common pre-drilling data packages, some of variables that needs to be specified are the horizontal displacement (vertical section) and total vertical depth (elevation target). The goals is to have a narrow range of HD and TVD as a result of simulating other adjustable parameters. Because of the elevation target and HD act as a dependent variables, the process then continued with adjusting the Kick-Off Point, End off Build, Inclination and build up rate in conjunction with the target depth in 3200 mMD. One criteria that is applied as a key parameter for completing the sensitivity analysis is Kick-off Points. As it mentioned before, the sensitivity analysis is applied to KOP number by putting the range between 200 mMD – 800 mMD. Likewise, the depth of EOB will be obtained from build up rate number until the the vertical depth has reached up to 2500 m and the HD has reached above 1600 m. The maximum inclination set below 50° to mitigate the high inclination well and avoid the following problems. While the BUR number was set below 3°/30 m to avoid the micro-dogleg that is inadvertenly formed higher than plan. The reference table can be seen in Table 1.

Table 1. Directional well design and variables for sensitivity analysis

Parameter	Design-A	Design-B	Design-C	Design-D
KOP (mD)	KOP @ 200 md	KOP @ 400 md	KOP @ 600 md	KOP @ 800 md
EoB (mD)	1000	900	1200	1400
Inclination	40°	40°	45°	50°
DLS	1.52	2.44	2.29	2.54
Azimuth	N 90° E	N 90° E	N 90° E	N 90° E
Final TD (mD)	3200	3200	3200	3200
Final TVD (mD)	2621	2622	2554	2484
Horizontal Displacement (m)	1682 m	1646 m	1638 m	1624 m

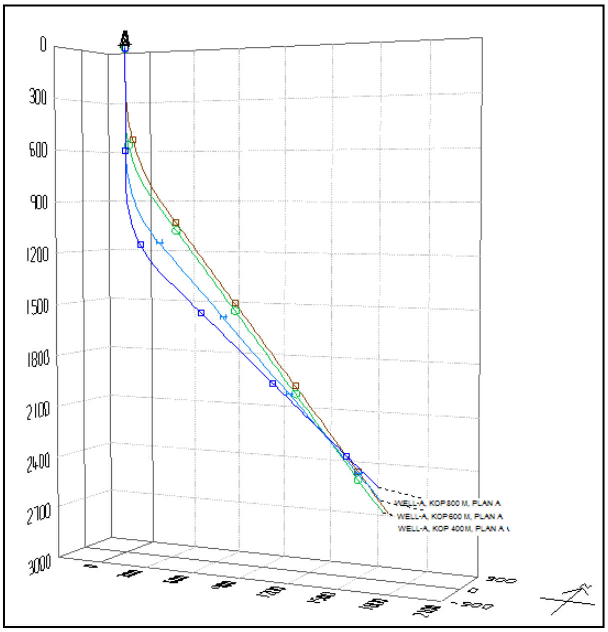


Figure 1. Offset wellplan 3-D View for design A, B, C and D

The simulation is split in four model design based on the difference between KOP number. The offset wellplan 3-D view shows in Figure 1. All of the wellplan design (A,B,C and D) has the same type of directional wellplan and run in the same wellbore condition. The tortuosity model for the geometry are given none for each design, assumed that the hole geometry are in ideal condition. After the directional well design has been created, the next step is simulating the torque and drag analysis for each design. The analysis for torque and drag was run for 9-7/8 inch hole section as the simulation interval in the wellbore design. The previous hole section are consist of production casing 13-3/8 inch cased hole (L-80, 68 ppf) set in 1200 mMD and 10-3/4 inch perforated liner hole (K-55, 40.5 ppf) set in 2200 mMD. The friction factor for both section are given 0.25, even though the the perforated liner should be more than it. For the 9-7/8 inch open hole section, the friction factor are given 0.5 and set in TD 3200 mMD without any volume excess. The friction factor for all sections are set on each operation type such as tripping, rotating on/off bottom, slide drilling and backreaming. The BHA design are representing the typical BHA for 9-7/8 inch hole section with dual stabilizer and Mud Motor for enhancing ROP performance. The BHA arrangement and well schematic shows in Figure 2. The drilling fluids composition is set for aerated-water type with density less than water density. The pump rate is set in around 750 - 850 gpm. The geothermal gradient is set for 0.89℃/30 m with surface ambient around 26℃. The mechanical limitation for top drive torque rating is set in 27 klbs-ft with the surface pressure loss set in 100 psi. For the Torque and Drag Normal Analysis, the operational parameters should be set for each condition. The operational parameters for each operation condition are given in Table 2.

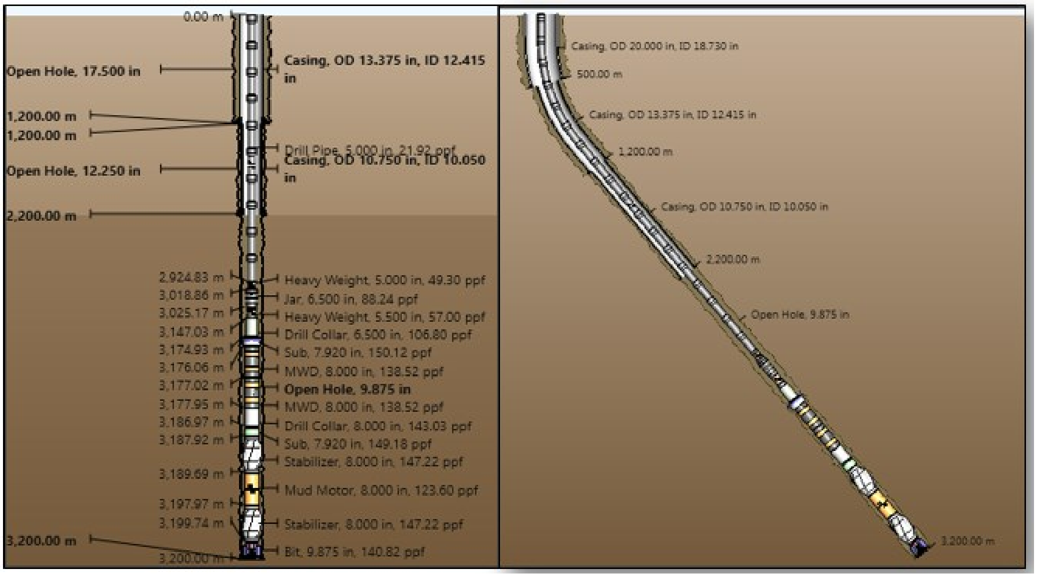


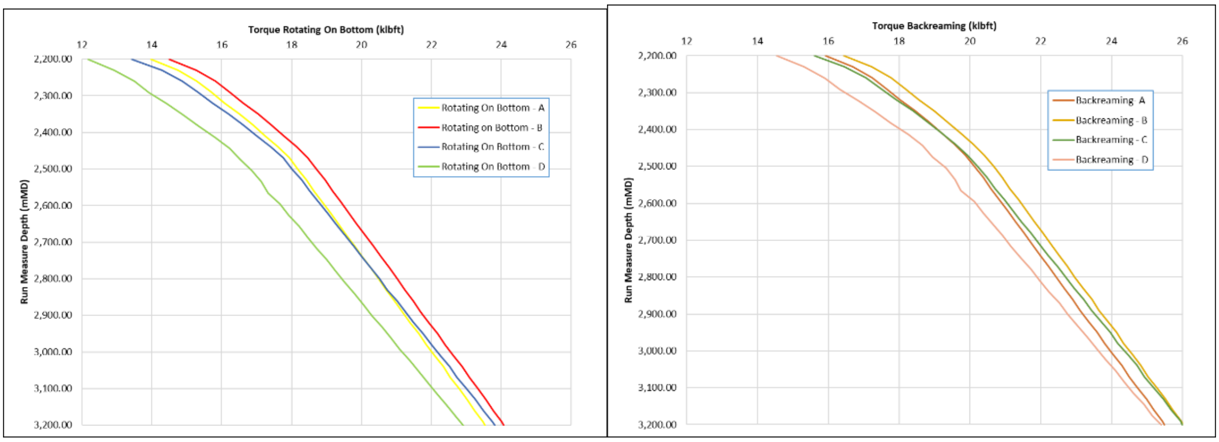
Figure 2. BHA Arrangement and Well Schematic

Table 2. Operational Parameters Design for Torque and Drag Analysis

Rotating On Bottom		Slide Drilling		Backreaming	
WOB	TQ @ Bit	WOB	TQ @ Bit	WOB	TQ @ Bit
22 kip	6 ft-kip	22 kip	6 ft-kip	22 kip	6 ft-kip
Mud Base Type		Water (6 ppg, 12.0 cp)		Flow Rate	800 gpm
Gradient Geothermal		0.89 °C/30 m		T-Ambient	26°
Hole Friction Factor		0.5		Hole Dia	9.875"
Casing Friction Factor		0.25		Hole Exces	0%

3. TORQUE AND DRAG SENSITIVITY ANALYSIS

The torque and drag analysis for each design are describe in roadmap calculation plots. The run parameters in dynamic plot started from top simulation interval in 2200 mMD and end in 3200 mMD. Based on this dynamic plot in 30 m step size, the torque and drag roadmap tend to increase along with adding depth. The torque analysis was focus on two operational conditions such as Rotating On Bottom and Backreaming. Meanwhile, in drag analysis there are 4 operational conditions to be focused such as Slack off Weight (Tripping in), Pick Up Weight (Tripping Out), Rotating On Bottom and Backreaming. To analyze each design, the range number of each operational condition were compared equally. The torque analysis graph and summary could be seen in Figure 3.

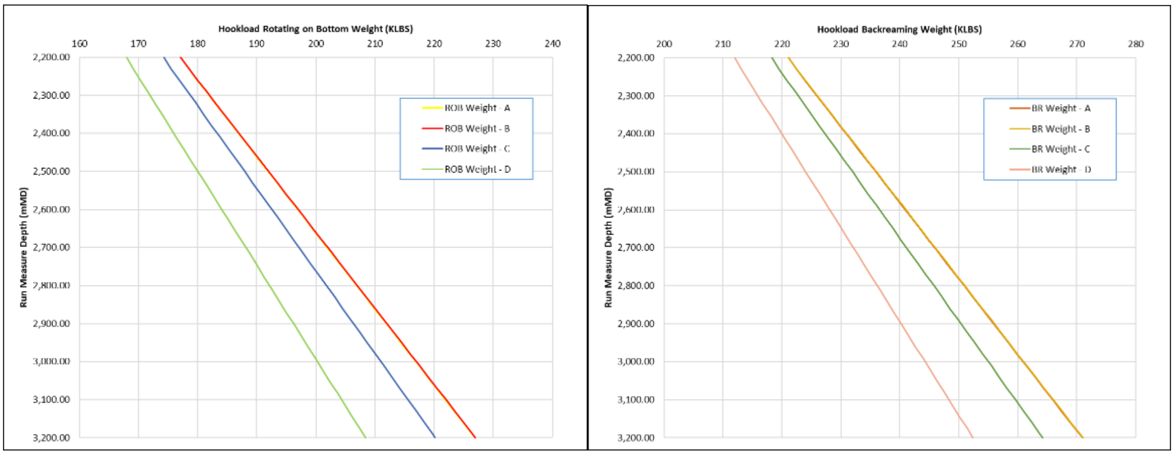


TORQUE	R.O.B		BR	
Design	Min	Max	Min	Max
A	13.97	23.54	15.91	25.49
B	14.50	24.08	16.44	26.03
C	13.43	23.82	15.61	26.00
D	12.18	22.92	14.55	25.40

Figure 3. Torque Analysis Graph & Summary

As can be seen in Figure 3, the highest range for torque level is taken from the Design-B, both in Rotating on Bottom or Backreaming operational conditions. In the R.O.B mode for Design-A, the torque level ranging between 14-24 klb-ft, while for Backreaming mode the torque level ranging between 16-26 klb-ft. In the meantime, the lowest range for torque level in the graph is located on Design-D. The torque value for R.O.B ranging from 12-22 klb-ft, while the the torque value for Backreaming ranging from 14-25 klb-ft. As for Design-A and Design-C, the range number for torque are similar between 13-23 klb-ft for R.OB and 15-26 klb-ft for Backreaming. Based on the comparison between each design, it can be discussed that selecting design-D will be the most secure options in terms of torque strength limitation. In case of actual operation, this range number will be increased reasonably and tend to approach the torque limit for the drill string. Design-A and C is a moderate option, while the Design-B is the weakest option. This pattern shows that the torque level is more depend on the length of wellbore where the Design-B has 500 m for the build section and 2300 m for the tangent section. 500 metres for build section is the shortest length between all design, hence the 2300 is the longest length in all design. The wellbore length is more sensitive than the difference in inclination. It may caused when the build section is shorter, the interval string below the build section would be in tension mode. The tensile force in that interval will increase, thus the side force number will also increase.

As for the Hookload Weight Analysis (Drag), the tendency of the range number between each design is quite similar with the torque analysis. Even though, the weight for R.O.B and Backreaming mode in Design-A and B is equal. The lowest range number for drag level still found in Design-D, with the value for R.O.B ranging between 168-208 klbs and Backreaming ranging between 212-252 klbs. Design-A and B value for R.O.B are ranging from 177-227 klbs and 221-271 klbs for Backreaming. The range value for Design-C is located between the other design. As for the drag analysis, the most selective design will be on Design-D, giving a small possibility of getting an overpull condition that leads to tensile strength limitation for the drillstring. If the options are set on the Design-B, it most likely the drill string will suffered along to the surface. It can be discussed that the drag calculation are really depend on how long does the contact area in string is located. Design-A and B has the longest tangent section (2200-2300 m) while the Design-B has the shortest tangent section (1800 m). The drag analysis and summary can be seen in Table 3.



HOOKLOAD	S/O		P/U		R.O.B		BR	
Design	Min	Max	Min	Max	Min	Max	Min	Max
A	169.4	188.2	237.5	329.6	177.1	227.0	221.1	271.0
B	167.7	186.4	240.0	332.1	177.1	227.0	221.1	271.0
C	168.7	181.5	233.3	326.0	174.3	220.2	218.3	264.2
D	166.8	173.6	222.0	312.1	168.0	208.4	212.0	252.4

Table 3. Drag (Hookload) Analysis Graph & Summary

Basically, the torque and drag analysis should be simulate in conformity resulting in combine load suffered by the drillpipe. But the combining load analysis would be saved and discussed later on the other paper. As it mentioned above, the safest design regarding both of torque and drag analysis is Design-D. It gives the lowest torque range level and lowest drag level if the subsurface target should hit the 2500 mTVD reservoir depth with H.D around 1600 m. If the Kick-Off Point should be shift upwards due to some technical reason (e.g. Anti-Collision Issue), the best choices are taken between Design-A or Design-C. The difference in putting the Kick-Off Point depth is provely affected the torque and drag analysis especially on the deep well geometry design.

By continuing the string analysis in Design-B, it gives a glance of another possibility problem. Based on the simulation, the depth range between 402 – 557 mMD in build section, the fatigue stress failure is happened on the Backreaming mode, where the bending and buckling phase has exceeding the fatigue endurance limit of the drillpipe. Meanwhile, the other operation condition has not having a stress failure or buckling limits. The table summary for string analysis can be seen in Table 4.

Table 4. String Analysis Table Summary for Design-B

Minimum WOB (Rotating) to Sinusoidal Buckle	72.0 klbs begins at 2.924 mD					
Minimum WOB (Rotating) to Helical Buckle	85.3 klbs begins at 2.924 mD					
Overpull Margin (Tripping Out)	53 klbs at 85% of Yield					
Pick-Up Drag	83.2 klbs					
Slack-Off Drag	62.5 klbs					
Torque Rating	27.0 klb-ft					
Block Weight	50.0 klbs					
Operation	**Stress Failure**			**Bucking Limits**		
	Fatigue	**85% Yield**	**100% Yield**	**Sinusoidal**	**Helical**	**Lockup**
Tripping In	√	√	√	√	√	√
Tripping Out	√	√	√	√	√	√
Rotating On Bottom	√	√	√	√	√	√
Slide Drilling	√	√	√	√	√	√
Backreaming	X	√	√	√	√	√
Rotating Off Bottom	√	√	√	√	√	√

4. LESSON LEARNED FROM ACTUAL WELL

In the actual drilling operation on PGE field, there are various cases that describe a correlation between hole geometry design and torque and drag value. For deep well case with final depth above 3200 mMD, there are two actual wells that can affirm the correlation between difference K.O.P depth that affect the torque and drag levels. Those two wells are named KRC-X1 and HLS-Z1 well. On the first well, the total depth is 3280 mMD with Kick-Off Point in 430 mMD, EOB in 1000 mMD and final angle is 30̊. On the 9-7/8 inch hole section, the drilling formation stages is having a high range number of torque and drag. The R.O.B operation conditions was ranging around 17-32 klb-ft untill the casing point, while the rotating weight levels is around 220-270 klbs. On the second well, the total depth is around 3280 mMD with KOP in 650 mMD, EOB in 1230 mMD and the final inclination is 39̊. On the 9-7/8 inch section, The torque on bottom levels are ranging around 16-26 klb-ft, where the rotating weight levels are ranging around 220-260 klbs. Even though there are many variables that drives the value, this pattern shows a glimpse of direct correlation between hole geometry design with the torque and drag value. Therefore, all of this data will help the engineers designing the next directional wellplan in terms of risk mitigation. The comparison between the two well are given in Figure 4.

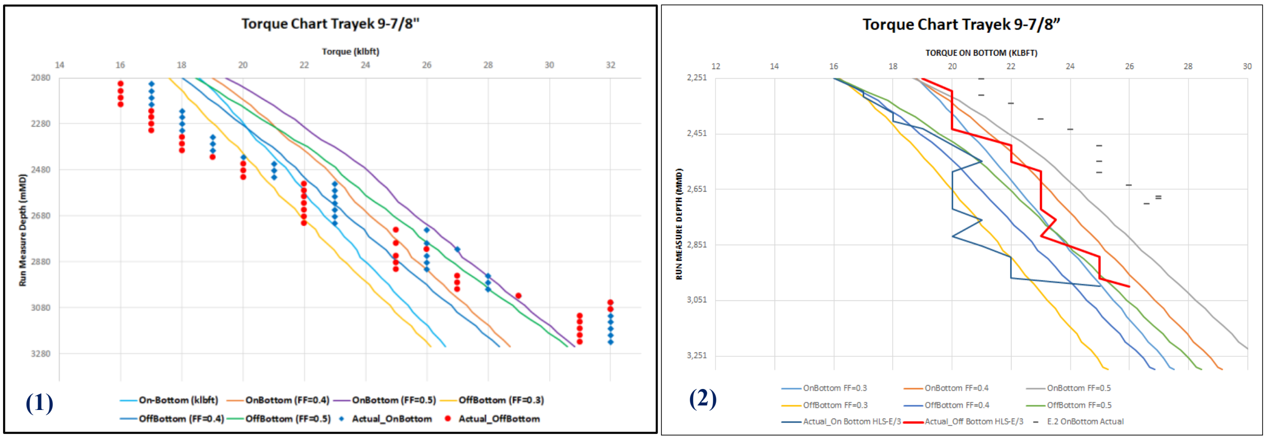


Figure 4. Wells KRC-X1 (1) and HLS-Z1 (2) Torque Roadmaps Plot for 9-7/8 Hole Section

5. CONCLUSION

As a conclusion, the torque and drag analysis is really important at the early phase of engineering design for geothermal deep well. From this technical point of view, the directional geometry design will drives the torque and drag analysis sensitively. By only selecting the depth of Kick-Off Point as the sensitivity variable, we can expect the possibility of having a drillstring and operational problem caused by the excessive torque and drag value. As can be seen in the previous part, the optimum directional well design is the design with deepest Kick-Off Point to reach the 3200 mMD depth and having the equal elevation and H.D in reservoir zone. But in the actual drilling scenario, sometimes the K.O.P depth should be shifted upwards or downwards due to technical reason (e.g anti-collision issue). By simulating for several directional scenario and carried out the torque and drag analysis within, the optimum design would be obtained and help the engineers minimize the future drilling problems and achieve the targets.

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