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Analysis of Torque and Drag in Abu Ghirab Horizontal Well Using Landmark (WellPlan) Software.

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Abstract— Studying and building torque and drag model close to the reality has become very important to achieve the well target successfully by analyzing the mechanical behavior of the drillstring and wellbore conditions. While drilling any particular well, tight hole conditions, sloughing shale, keyseating, differential sticking, sliding wellbore friction and accumulation of cuttings due to inefficient hole cleaning result in excessive torque and drag which usually occur together. In this study, Halliburton's Landmark software (WellPlan) was utilized on selected well; Well-AG horizontal well in Abu Ghirab oilfield, Missan oilfields. Modeling of Torque and drag is important to predict the drillstring effective tension, buckling, torque, slack off and pick up drag, weight on bit and fatigue ratio which can be considered as drillstring operational windows. Three main processes are used in torque and drag modeling. First, utilizing offset wells data; hierarchical data, survey data, casing and open hole section depth, drillstring and BHA specifications, drilling fluid properties, subsurface temperature and operations parameters. Correction hookload weight, using stiff string and using viscous torque and drag option were included in the second process. Third process comprised friction coefficient calibration with actual field data.Drilling operations, tripping in/out the hole, rotating on bottom, rotating off bottom, Backreaming and slide drilling in open hole section 8 1/4 inch was studied.The most significant conclusion is as the inclination angle of the well path was increased above 76° and reached 88.2°,the drillstring buckling can be occurred with much higher WOB (compression force) requirement. The studied well was closed to buckle at 2408 m (MD). Calibrated friction coefficient in WellPlan software depending on actual well data where used in tripping in/ out and rotating off bottom operations.

Keywords— Torque, Drag, Buckling, Friction factor, Landmark Software.

1. Introduction

Torque and drag due to friction between drillstring and wellbore wall is one of the important and critical issues which limit drilling operations progress with depth. Therefore, many studies have been performed on the modeling of torque and drag [1]. Software for torque and drag modules has been advanced and utilized in the oil industry. It is of the most importance in keep away from drilling problems and allowing for more drilling, especially in extended reach and complex wells, where the loads are usually close to the limits of the available instruments and materials [2].

Modeling of torque and drag is usually used to minimize drag and torque forces in trajectory design, determine problematics arising reduce drag and torque through drillstring design, determine the onset drillstring buckling and the possibility of reciprocating casing during cementing operations. In addition, hole cleaning in real time and monitoring the friction while running casing [2].

1.1 *Torque and Drag*

The moment necessary to rotating the entire string and the bit on the bottom of the wellbore is defined as Torque (Figure 1). This moment is utilized to overcome the rotational friction opposed to the wellbore, viscous force between drillstring and drilling fluid in addition to bit torque [3]. Additional force necessary for moving the drillstring up or down in the wellbore as a result of the generated frictional forces and contact loads is defined as Drag as shown in Figure 1[4].

The magnitude of the drag and torque is determined by the magnitude with which the drillstring contacts the wellbore and the coefficient of friction between the wall and drillstring [5].

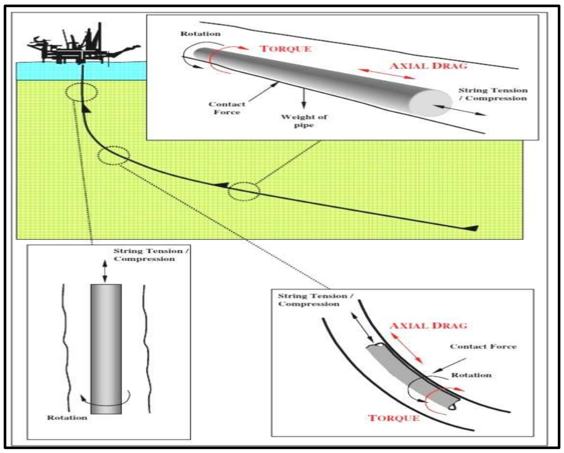


Figure 1: Drilling Forces in the Wellbore [6].

1.2 *Mathematical Models*

Two different mathematical models, soft string and stiff string are applied for drag and torque analysis. These two models were developed to illustrate the mechanical behavior of the drill string inside the wellbore. The two models presented are three dimensional models [7].

1.2.1 Soft String Model

The soft string is also referred to as "chain", "rope" or "cable" model. This model is presented by Johancsik et al. (1984) [8]. The soft string module is widely applied in the oil industry due to its simplicity and sufficient accuracy and this module which most commercial simulators like WellPlan are based on [7].

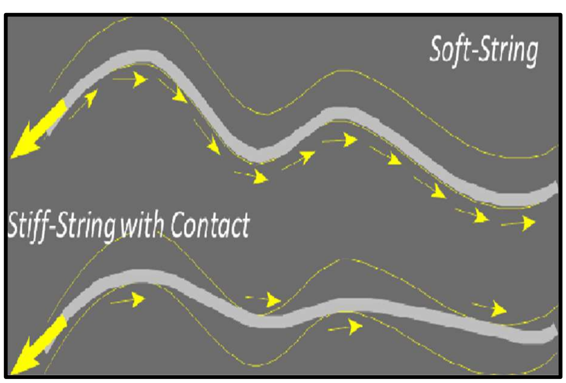


Figure 2: Soft String and Stiff String Models [9].

Soft string module supposes that sliding friction is the primary source of drag and torque forces in a directional borehole, and that the friction forces result from contact of the string along with the wellbore [7] as shown in Figure 2 [9].

In general, oil wells comprise of curved sections, inclined (straight), and vertical. All loads must be processed with respect to a given well trajectory (measured depth, inclination and azimuth), when calculating torque, drag and buckling tensile limits and stress in the drillstring [7,10].

Adrillstring segment of a simple free-body diagram with respective forces is shown in Figure 3 [5]. The principle Coulomb frictional load, axial loads and other effects are used to each segment. Every of the short elements contribute small parts of weight, axial drag and other affects. The sum of these loads generates the total forces on the drillstring [11].

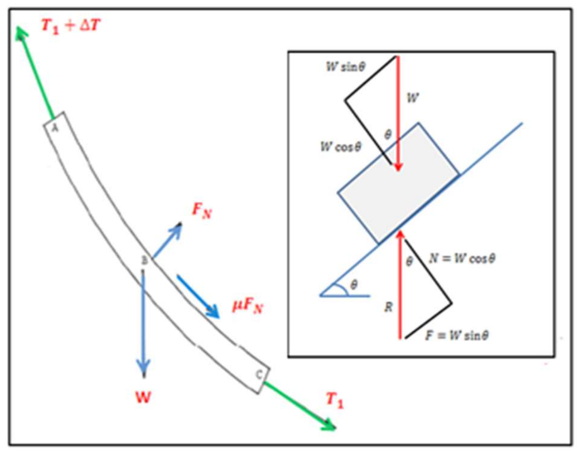


Figure 3: Loads Acting on the Drillstring Segment ΔL while Pulling Out of the Hole [5].

The drillstring sited in a curved borehole under tension will exert a load proportional to the tension and change of dogleg severity (curvature rate). As shown in Figure 3, the resultant normal force is the sum of the normal loads due to pipe weight and tension.

If y-axis is supposed to be in the horizontal plane along the axis of the hole, the x-axis is supposed to be in the vertical plane and the, then summing the loads in the x and y direction will yield the normal forces:

$$F_x = 2T \sin\left[\frac{\Delta\theta}{2}\right] + W\sin\theta_{avg} \quad (1)$$

$$F_y = 2T \sin\left[\frac{\Delta A}{2}\right] \sin\theta_{avg} \quad (2)$$

Where, $\Delta\theta$ is a change in inclination over ΔL , in degrees and ΔA is a change in azimuth over ΔL, in degrees.

The resultant normal force due to tension is:

$$F_N = \sqrt{\left\{2T\sin\left[\frac{\Delta\theta}{2}\right] + W\sin\theta_{avg}\right\}^2 + \left\{2T\sin\left[\frac{\Delta A}{2}\right]\sin\theta_{avg}\right\}^2} \quad (3)$$

The normal force times the friction coefficient is equal to the drag force:

$$T = \mu F_N \quad (4)$$

Multiplying the normal force at each point along the drillstring and by the coefficient of friction will yield the raised tension caused by drag. The sum of the weight and drag will equal the drillstring tension at every point in the well.

The tension of the drillstring at point "C" is described by T_1 and the tension at point A will be T_2 or $T_1 + \Delta T$, where the increase in tension because of friction and weight is ΔT. For further accurate calculations, the length of ΔL should not exceed 100 feet [5].

The calculation begins at certain point of known tension. In generally cases, the point of known tension is the bit where the tension is zero if not the bit is stuck. Drag always proceeds in the opposite direction that the drillstring movement. While tripping out, the drag will raise the tension in the drillstring. While tripping in the hole, the drag will reduce the tension in the drillstring [5].

While pulling out of the hole:

$$T_2 = T_1 - W\cos\theta_{avg} + \mu F_N \quad (5)$$

While running in the hole:

$$T_2 = T_1 - W\cos\theta_{avg} - \mu F_N \quad (6)$$

An additional drag force occurs due to the drill string buckling while tripping in the hole. Dawson and Paslay (1984) in [12] developed an equation for the critical buckling force for sinusoidal buckling in an inclined hole. In reality, the drag will increase due to the drillpipe will experience the sinusoidal buckling before helical buckling (Figure 4). However, the torque and drag model is simple and helical buckling will be ignored [5].

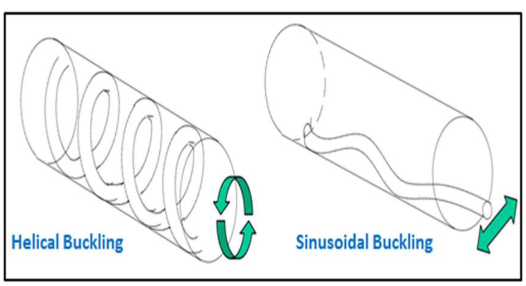


Figure 4: Sinusoidal and Helical Buckling [13].

An additional normal load is imposed upon the drillstring, when the compressive forces in the drill string exceed the critical buckling load. This load must be added to the normal force produced by bending and tension (or compression). Also, in vertical portion of the well with no curvature, buckling lead to additional drag forces [5].

The same equations for determining the normal force (Equation 3) are used to calculate, the torque in a directional well. The only difference is that the hole drag is not considered in equation 7. When the drillstring is rotated, only the weight component and bit weight contribute to the tension in the drillstring and the drag forces will be nullified. Some drag will still be existing when rotating drillstring while tripping in the borehole, i.e. if movement of pipe is fast, all the drag loads are not nullified [5].

When rotating, the tension at every point in the well T_2 and the rotating weight would be the value of T_2 at the surface:

$$T_2 = T_1 - W\cos\theta_{avg} \quad (7)$$

The force resisting rotation of the drillstring is the normal force times the coefficient of friction.

As mentioned, the torque is computed in segments ΔL along the drillstring. The torque (M_1) at the bottom of segment ΔL and the torque (M_2) at the top of segment ΔL is proposed in the following equation:

$$M_2 = M_1 + \mu F_N R \quad (8)$$

Where R is the radius of the pipe, but in most situations, only the drillpipe tool joint contacts the wall of the hole and the radius of the tool joint should be used to calculate the torque [5].

1.2.2 Stiff String Model

The shortcomings of soft string model was discussed and pointed out by Ho. H-S, (1988). The weakness of the soft string model was identified and based on a soft string concept. The effect of drillstring stiffness, stabilizer placement, and borehole clearance is ignored. Therefore, soft string model shows reduced sensitivity to local borehole crookedness (tortuosity) and underestimates the torque and drag [14].

Drillstring stiffness into consideration, radial clearance, dog leg severity and tortuosity of well trajectory are needed in torque and drag model. More comprehensive mathematical models include finite difference; finite element and semi-analytic methods are used to take into consideration the mentioned physical effects. Besides sufficient resolution and availability of survey and equipment data [15].

Many attempts have been made to create a model which accounts drillstring stiffness and radial clearance and such modules are called stiff string module. Such module must give higher side load in a bend, and possibly lower side load at the end of the bend where the pipe straightens, due to the stiffness of the drillstring. As mentioned, the stiff string modules were improvement to overcome the limitations of soft string modules. Over the smooth wellbore geometry, both soft and stiff string modules show similar outcomes, but they give different predictions when the wellpath is highly doglegs with highly tortuous. Previously stiff string models are not optional for real time drag and torque monitoring due to the some time necessary for its application [2] but later using WellPlan simulator is based on stiff string model and soft string model which are needed few minutes or second for its application. Stiff string model was derived by Mirhaj et al. (2016) [1] and the new stiff string axial load is the superposition of 3D soft string axial load and the additional frictional force as shown in the following equation [1]:

$$F_2 = F_1 e^{\mu|\propto 1-\propto|} + AW\Delta L \left(\frac{\sin\theta_2 - \sin\theta_1}{\theta_2 - \theta_1}\right) \qquad (9)$$

F_2= axial force (drag) at the end of curved section with taking pipe stiffness into account (N), F_1= axial force (drag) at the beginning of curved section with taking pipe stiffness into account (N), μ= friction coefficient, ∝ = dogleg angle (degree), A = azimuth (degree), W= unit weight of the pipe (kg/m), ΔL = pipe incremental length (m) and θ = inclination angle (degree).

2. Case Study

In this study, one horizontal well was selected (Well- AG) to develop torque and drag model in Abu Ghirab oilfield that located in Missan province in southeastern of Iraq and close to the Iraq-Iran border (Figure 5). Abu Ghirab is oilfield structurally, ranged about 30 km times 6 km with north and south domes, which is a NW-SE long axis anticline. From top to bottom, the strata drilled in Abu Ghirab oilfield include Tertiary Upper Fars, Lower Fars, Tertiary Jeribe and Cretaceous Nahr Umer Formations. The Lower Fars has 5 litho-logical members. Tertiary Asmari is the main reservoir in Abu Ghirab oilfield. Top of Asmari reservoir (is divided into north dome and south dome based on structure and OWC) in Abu Ghirab oilfield with its well locations is shown in Figure 6.

Well-AG was drilled to 3260 m total depth. Casing of OD 9 5/8 inch was set at 2939 m and the was drilled to total depth of 8 ¼ inch open hole section.

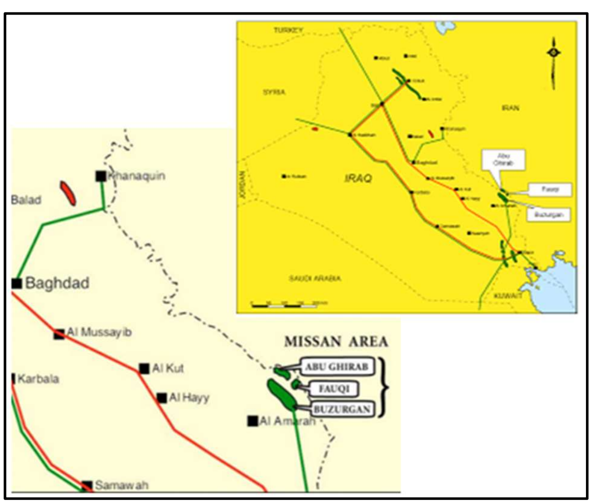


Figure 5: Missan Oilfields [16]

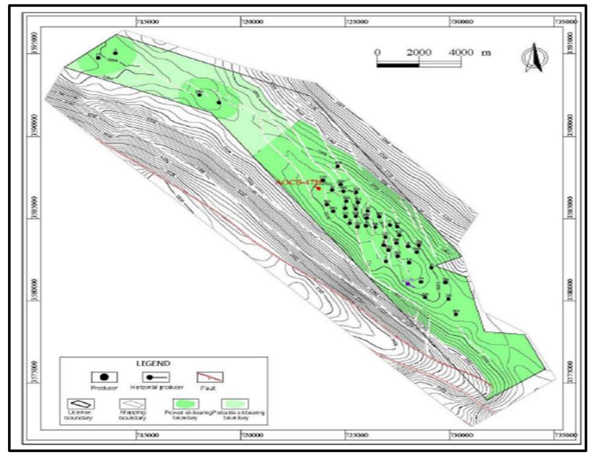


Figure 6: Wells Location on Top of Asmari Reservoir in Abu Ghirab Oilfield [16].

2.1 *Steps of Analysis (Methodology)*

Workflow steps for torque and drag model that was followed while applying WellPlan software is shown in Figure 7.

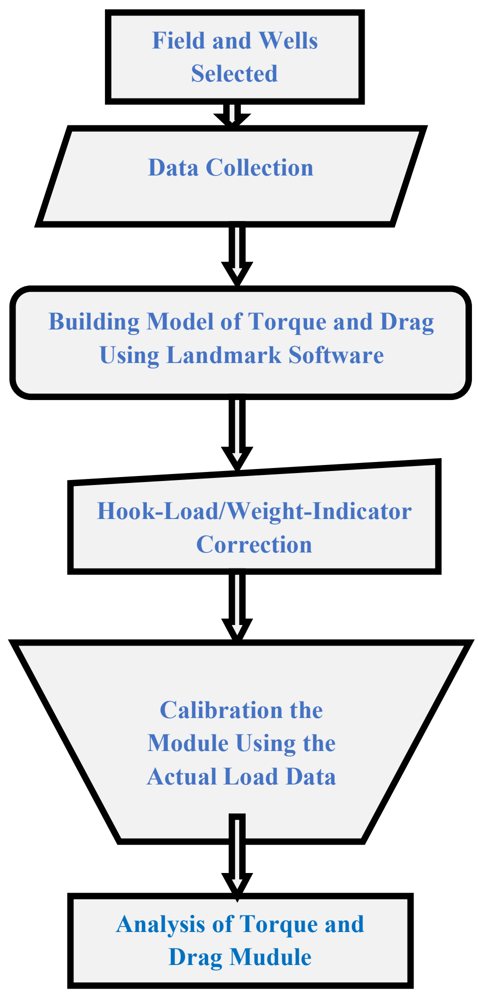


Figure 7: Landmark (WellPlan) Software Flowchart.

2.2 *Data Collection*

Data were obtained from [Final Well Report (FWR), Slide and Rotary Drilling Report (Steering Sheet), Drilling Program, Directional Well Report, Casing Tally, BHA Report and Daily Drilling Report (DDR)].

2.3 *Building Model of Torque and Drag Using Landmark Software*

The following steps explain the torque and drag model application using Landmark (WellPlan) software:

a. ***Creating the Data Hierarchy*****:** The systematic organization of data is shown in Figure 8.

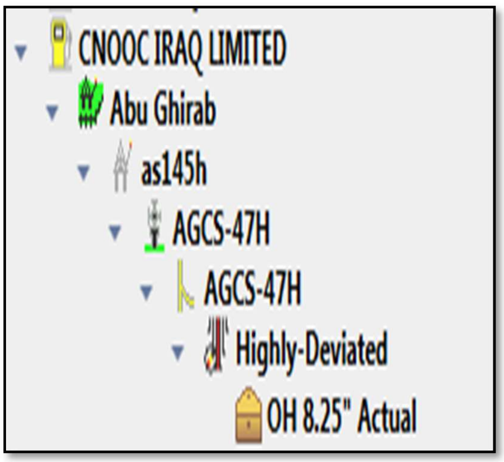


Figure 8: Data Hierarchy of Well-AG.

b. ***Open the Case:*** This step include the following:

- ***Create a WellPath of Well***

This process is done by entering survey points data directly into the spread sheet located at WellPath Editor Tab. Values of MD (Measured depth), Inc. (Inclination) and Az. (Azimuth) must be entered for each survey point. The other information, True vertical depth (TVD), Dog Leg Severity (DLS), Vertical Section (VS), Northing Coordinate (NS), Easting Coordinate (EW) and Build Rate were calculated using Minimum Curvature method.

- ***Create the Hole Section***

The specification of cased and open hole sections length is illustrated in Figure 9. Tortuosity should not be applied on actual Wellpath data.

- ***Create a Drillstring***

The drillstring specifications and details that are running into the hole were entered. Drillstring data of Well-AG were entered from the surface to the total depth as shown in Figure 10.

- ***Creating Mud (Drilling Fluid)***

The properties of drilling fluid (mud) are illustrated in Table A.1 (Appendix) and shown in Figure 11. Type of base mud, density, plastic viscosity, yield point, rheological model and pump rate are required.

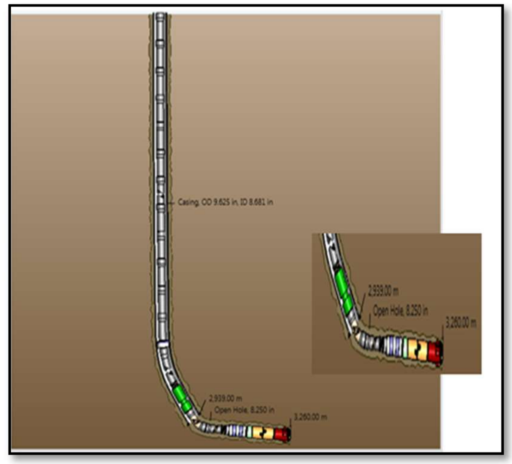


Figure 9: Hole Sections of Well-AG.

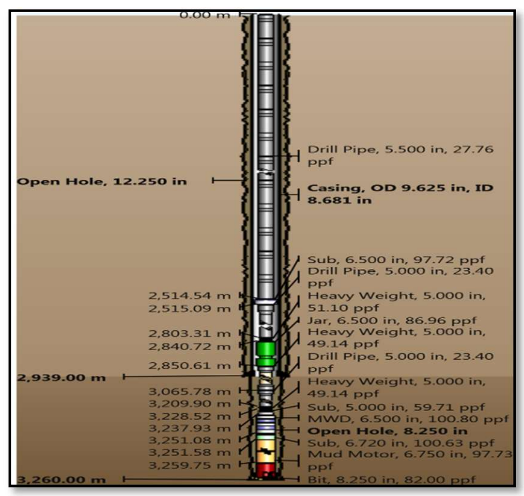


Figure 10: Drillstring Details of Well-AG.

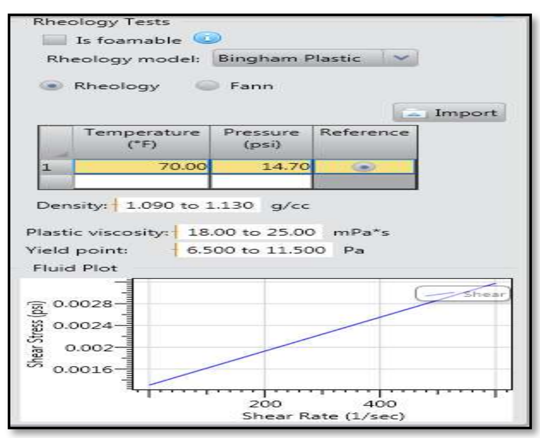


Figure 11: Drilling Fluid Data of Well-AG.

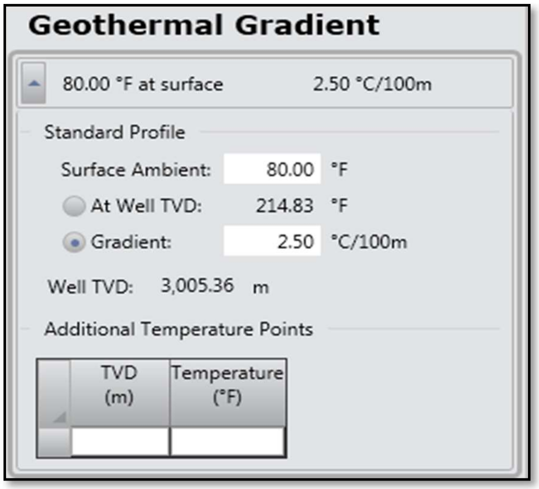


Figure 12: Geothermal Gradient of Well-AG.

- ***Add Subsurface Properties***

Subsurface properties that define geothermal gradient were entered as shown in Figure 12.

- ***Add Operations Parameters***

Tripping and Drilling (T&D Normal Analysis) is selected and the operation parameters are entered for Tripping Out, Tripping In, Slide Drilling, Rotating On Bottom, Backreaming, Rotating Off Bottom that required as shown in Figure 13.

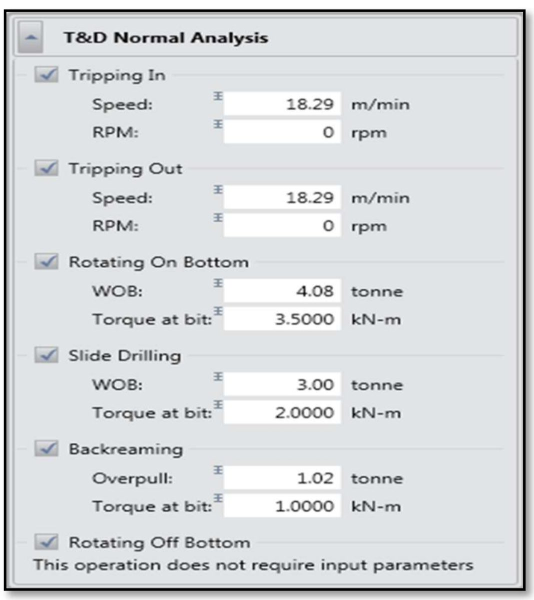


Figure 13: Normal Analysis Operational Parameters of Well-AG.

c. ***Analysis Settings***

The Analysis settings to configure the analysis parameters settings pertaining to the outputs were added to the Output Area. If the parameters are not required for the displayed plot, the section will not be visible. This analysis can be made by common options which include the following steps:

- ***Active fluid***

The fluid that is used in this analysis was selected from this option. Only one fluid can be used in this analysis is presented in Table A.1 (Appendix).

- ***Pump rate***

Pumping rate should be specified. In Well-GA, 1500 L/min was applied.

- ***The Run Parameters***

These parameters specify the depth of the bottom of the drillstring at numerous intervals along the wellbore for the purpose of analysis as shown in Figure 14. These depths were used to generate output for the HookLoad, Torque Point, Minimum WOB, Friction Calibration, and Slack Off/Pick Up.

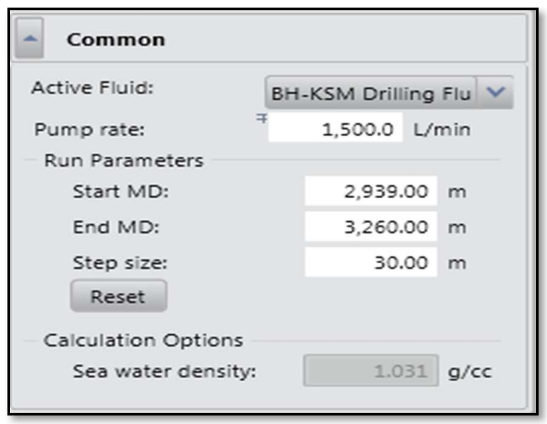


Figure 14: Common Options of Well-AG.

2.4 *Hook-Load /Weight-Indicator Corrections*

a. ***Block Weight***

The weight of the traveling assembly is specified and it is the weight indicator reading when the pipe is in the slips and has a value of 25tons.

b. ***Use Stiff String***

The stiff string model was used to determine the difference inside force from the resulting pipe position and the bending curvature. The stiff string module computes the additional side load from stiff tubular bending in a curved hole, as well as the decreased side loads from pipe straightening due to pipe/hole clearance. This model is complex, and therefore takes a significantly more time to run than the soft string model. Also, this model views the position of the drillstring in the borehole.

c. *Use Viscous Torque and Drag*

Viscous drag is further drag force acting on the string due to hydraulic affects while tripping or rotating. The magnitude of the effects depends strongly on the rheological properties of the chosen fluid.

d. *Use Maximum Overpull*

Specify the percentage of yield that is needed to be maintained while calculating the maximum overpull. Maximum overpull is the margin of extra weight above the static hook load which the string can be handled when pulling out of hole before the specified percentage of yield is exceeded,. In this case study, 90 % of yield was used.

2.5 *Calibration the Module by the Actual Load Data*

Actual load option was used to enter actual loads for friction calibration. Friction calibration plot was used to calibrate friction factors within an open hole section. Friction factors can be manually adjusted to achieve the best curve fit to the actual loads data. Friction factor can be selected to apply it in a hole section, or for an operation. Actual loads data were obtained from rotary and sliding drilling report, and the friction calibration was made through Figures 15 to 17.

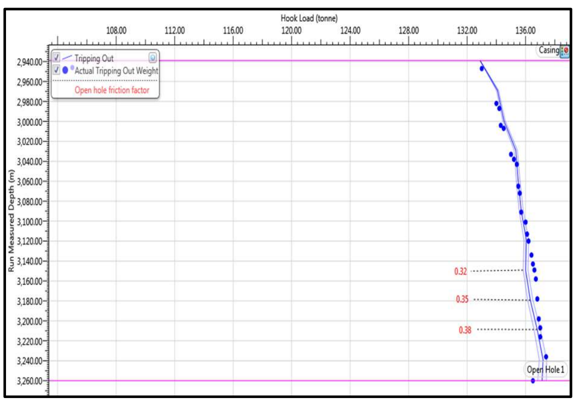


Figure 15: Friction Calibration during POOH of 8.25" BHA of Well-AG.

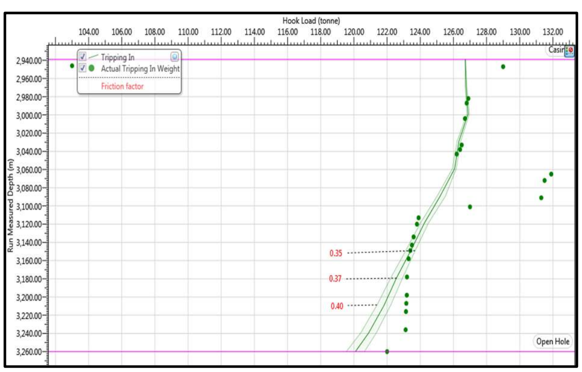


Figure 16: Friction Calibration during RIH of 8.25" BHA of Well-AG.

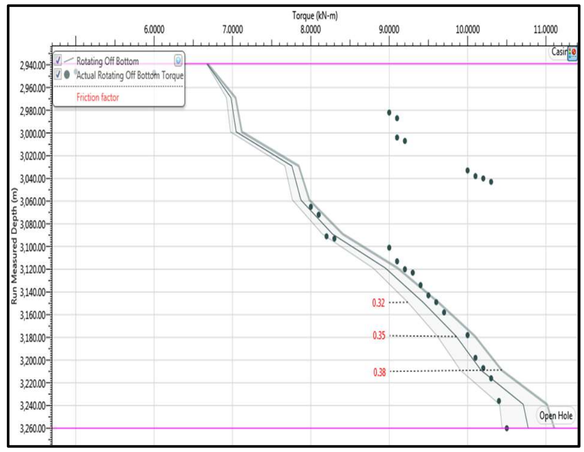


Figure 17: Friction Calibration during ROFFB of 8.25" BHA of Well-AG.

3. Results and Discussion

This section presents the results of calculations that required in Landmark (WellPlan) software and developing torque and drag model.

3.1 *General Output*

The geometry of this well is shown in Figure 18 to Figure 22. These figures illustrate vertical section, plan view, inclination vs. measured depth (MD), azimuth vs. measured depth (MD) and dogleg severity vs. measured depth (MD) respectively. Inclination of this well increases with measured depth and reached 88.2 degree at 3260m true vertical depth that would be horizontal as shown in Figure 20. Also, this well has high value of dogleg severity; it reached maximum value of 9.702 degree/30m at 2984.96 m (MD) as shown in Figure 22.

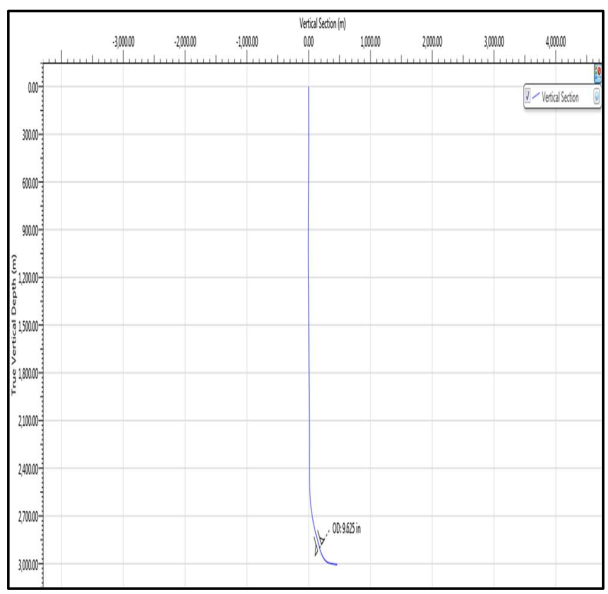


Figure 18: Vertical Section of AG-Well.

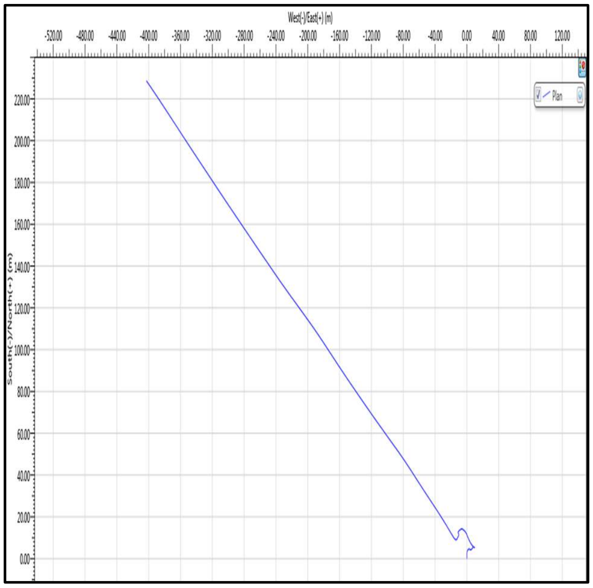


Figure 19: Plan View of Well-AG.

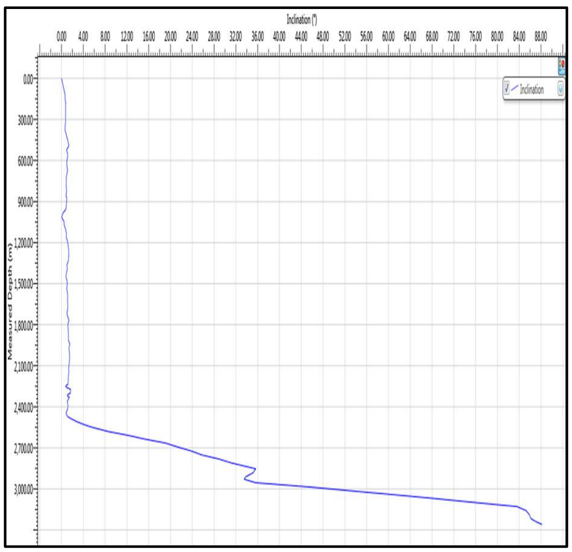


Figure 20: Inclination vs. MD of Well-AG.

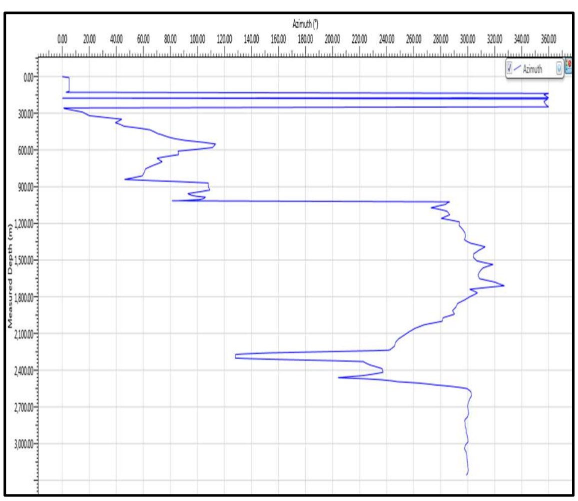


Figure 21: Azimuth vs. MD of Well-AG.

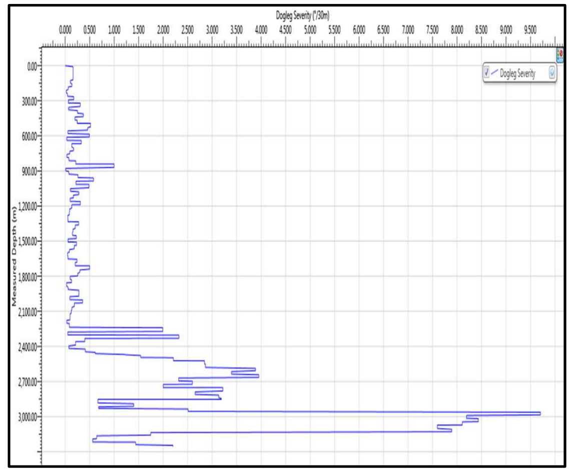
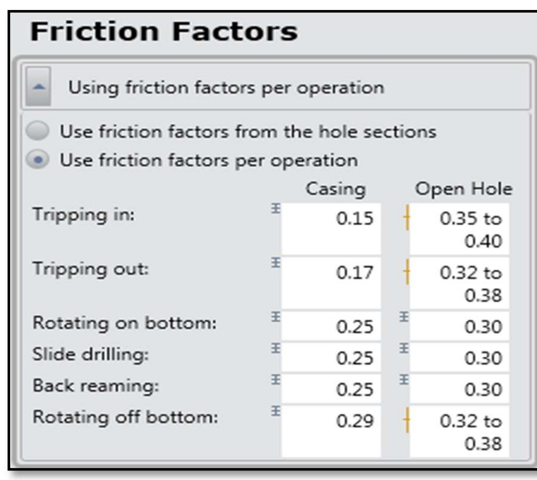


Figure 22: Dogleg Severity vs. MD of Well-AG.

3.2 *Coefficient of Friction Calibration*

The analysis and calibrated results show that the friction factors for different operations in 8 ¼ inch open hole section are within the range of 0.35 to 0.40 at tripping in operation, 0.32 to 0.38 at tripping out operation, and 0.32 to 0.38 at rotating off bottom operation. Due to lack in sufficient operating conditions in open holesection for rotating on bottom, slide drilling and back reaming, the friction factor was assumed to be 0.3 as shown in Figure 23. Another reason of using Figure 23 is due to the lack sufficient operating conditions in cased hole (OD 9 5/8 inch), the friction factors were assumed to be 0.15 in tripping in operation, 0.17 in tripping out operation, 0.29 in rotating off bottom operation and 0.25 in rotating on bottom, slide drilling and Backreaming [5].



Friction Factors

Using friction factors per operation

Use friction factors from the hole sections

Use friction factors per operation

	Casing	Open Hole
Tripping in:	0.15	0.35 to 0.40
Tripping out:	0.17	0.32 to 0.38
Rotating on bottom:	0.25	0.30
Slide drilling:	0.25	0.30
Back reaming:	0.25	0.30
Rotating off bottom:	0.29	0.32 to 0.38

Figure 23: Friction Factors for Tripping In/Out, Rotating On Bottom, and Rotating Off Bottom, Backreaming and Slide Drilling Operations of Well-AG.

3.3 *Effective Tension*

The effective tension during tripping in/out can be used for determining when drillstring buckling may be occurred. The loads that required to sinusoidal or helical buckling of the drillstring during the tripping in/out operations are shown in Figure 24. The drillstring will not buckle at any depth in AG-Well, because the effective tension does not exceed the buckling load and the tension limit (the minimum yield strength for the drillstring components). Also, Figure 23 illustrates that the effective tension of tripping in is less than tripping out which leads to a high probability of a drillstring buckling at tripping in operation. Extreme care must be developed during tripping in because the drillstring will be very close to the buckling at 2408 m MD.

The loads that required to sinusoidal or helical buckling the drillstring during the rotating off bottom, rotating on bottom, backreaming and slide drilling operations are shown in Figure 25. The drillstring will not buckle at any depth in AG-Well because the effective tension does not exceed the buckling load and the tension limit (the minimum yield strength for the drillstring components). The effective tension during slide drilling is less than other operations as shown in Figure 25 which leads to a high probability of a drillstring buckling at slide drilling. Extreme care must be developed during slide drilling because the drillstring will be very close to the buckling at 2408 m MD.

Additionally, during rotating off bottom, backreaming and tripping out operations, the drillstring is under tension from surface to total depth. While slide drilling, tripping in and rotating on bottom operations at 2850 m, 2904 m and 2967 m (MD) respectively, the drillstring is partially under tension and partly in compression which means, a compressive load should be required at the surface to induce bit weight needed.

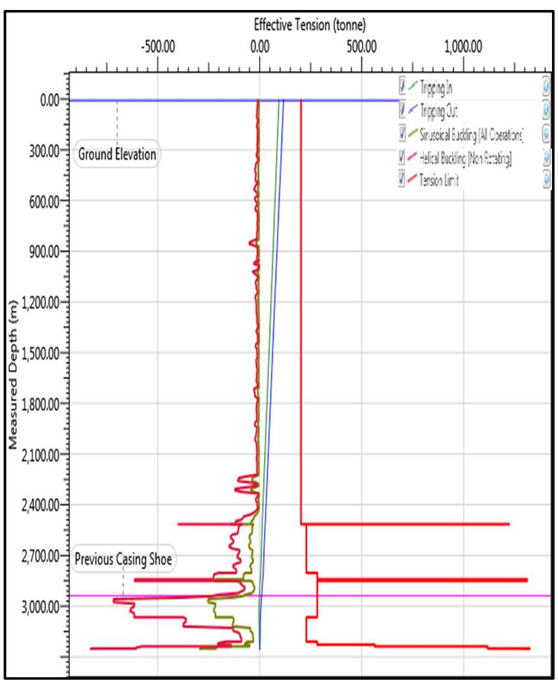


Figure 24: Effective Tension during Tripping In and Tripping Out of AG-Well.

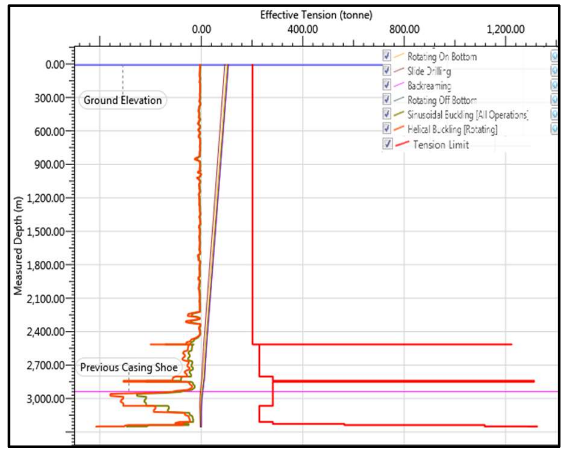


Figure 25: Effective Tension during Rotating On Bottom, Rotating Off Bottom, Backreaming and Slide Drilling of Well-AG.

3.4 *Torque Plot*

Drillstring torque during rotating off bottom, rotating on bottom, tripping in/out, slide drilling and backreaming operations in Well-AG are illustrated in torque plot (Figure 26). The torque plot shows that the torque limit is not exceeded and the tool joints for the drillstring are not liable to over-torque or break. In addition, the rotating on bottom torque is greater than other operations. The torque at the surface has a high value and this value decreases with increasing measured depth until it reaches the minimum value at the bit, which is known as torque on bit (TOB).

The torque values while tripping out and tripping in operations are equal to zero because of the fact that there is no rotation of the drillstring. Torque values during slide drilling operation is equal to 2 kN-m (torque on bit) and don't increase because there is no rotation of drillstring in slide drilling operation.

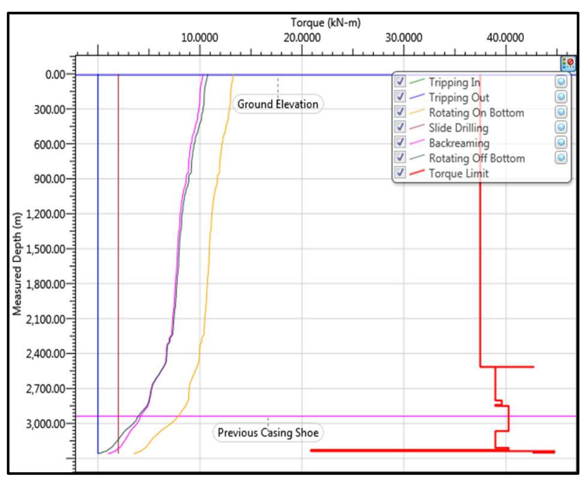


Figure 26: Torque Plot during Tripping In/Out, Rotating On Bottom, and Rotating Off Bottom, Backreaming and Slide Drilling Operations of Well-AG.

3.5 *Minimum Weight on Bit Chart*

Minimum WOB to initiate sinusoidal or helical buckling is shown in Figure 27 for two operations (rotating and slide drilling). Therefore, more attention are required during drilling 8 ¼ inch open hole section from 2939 m to 3260 m (MD) in Well-GA to ensure that the WOB is kept less than the present values in Figure 27 at the corresponding bit depth. Once the WOB exceeds the minimum WOB at the corresponding bit depths, the drillstring will start buckling according to the corresponding buckling mode (sinusoidal or helical).

During rotating operation, the minimum WOB value of 17.24 tonne at 2969 m (MD) refers to sinusoidal buckling (green line) and minimum WOB value of 22.72 tonne at the same measured depth refers to helical buckling (red line) (Figure 27). The difference between these two values (5.48 tonne) is considered to be large change from sinusoidal to helical buckling. Also, the smallest difference of 1.2 tonne is between minimum WOB causing sinusoidal buckling and helical buckling at 3119 m measured depth. Therefore, the driller should be careful at this depth because of the small change from sinusoidal to helical buckling.

During sliding operation, the minimum WOB of 12.65 tonne at 3089 m (MD) to cause sinusoidal buckling (orange line) and the minimum WOB of 18.57 tonne at 3260 m (MD) to cause helical buckling (blue line) (Figure 27). Also, Figure 27 illustrates that the smallest difference of 3.46 tonne is between minimum WOB causing sinusoidal buckling and helical buckling at 3149 m (MD). Therefore, care must be taken during sliding operation.

Generally, the minimum WOB values versus measured depth during rotating and sliding operations continue to decline to a measured depth of 3080 m (Figure 27). The critical force causing tubular buckling is higher than that at measured depths more than 3080 m. Due to the drillstring lying on the wellbore wall of 8 ¼ inch open hole section with an inclination above 76°, higher forces enable to buckle the drillstring and higher frictional force between the drillstring and the borehole wall should be overcome.

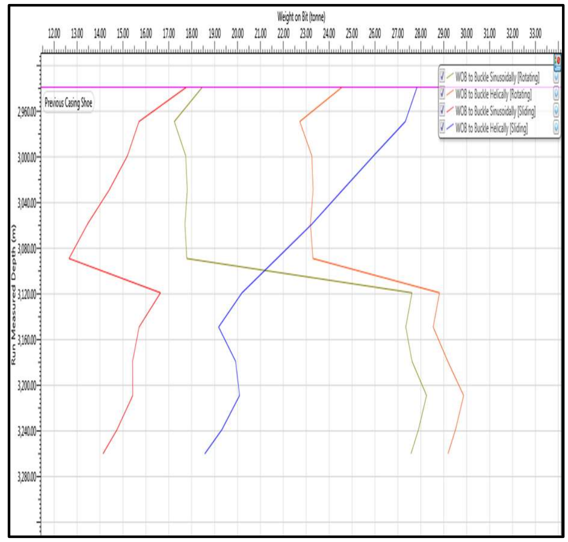


Figure 27: Minimum Weight on Bit Chart for Two Operations (Rotating and Sliding) of Well-AG.

3.6 *Slack Off and Pick Up Drag*

Drag refers to the cumulative force required to slack off (tripping in pipe) and pick up (tripping out pipe) is shown in Figure 28. The drag forces can be comparable to the hook load (weight of the drillstring measured at the surface). Slack off drag (green line) and pick up drag (blue line) increase slightly with increasing measured depth to 2500 m and followed by a sudden increase to total depth due to the dramatically increase in inclination and dog leg severity.

Pick up drag values are greater than slack off drag to a measured depth of 3179 m. As measured depth increases, pick up drag values are less than slack off drag because the inclination become approximately 90 degree or the well changes to be horizontal which needs high force to run the drillstring in the well. Also, Figure 28 shows that the maximum slack off drag and maximum pick up drag are 12.5 and 12.1 tonne at total depth respectively.

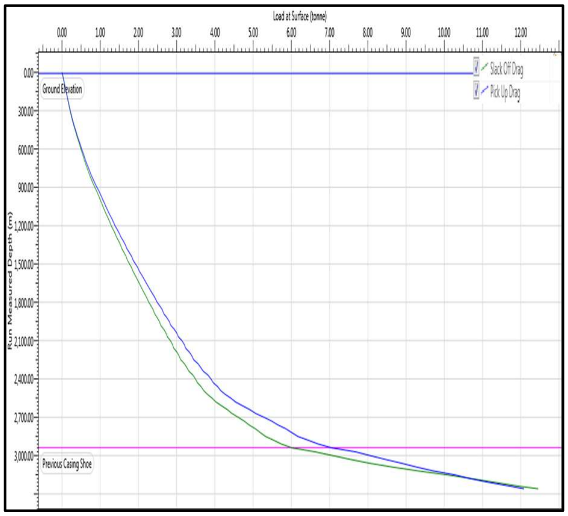


Figure 28: Slack Off and Pick Up Drag of Well-AG.

3.7 *Fatigue Ratio Plot*

Fatigue ratio from surface to total depth (TD) of three operations including backreaming, rotate off bottom and rotate on bottom is shown in Figure 29. When the drillstring is run in the wellbore from 2984.96 m to 3128.94 m (MD), the maximum values of fatigue ratio of backreaming, rotate off bottom and rotate on bottom operation are within range of 0.509 to 0.607 due to high dogleg severity within range of 7.892 to 9.702 degree/30m at this interval.

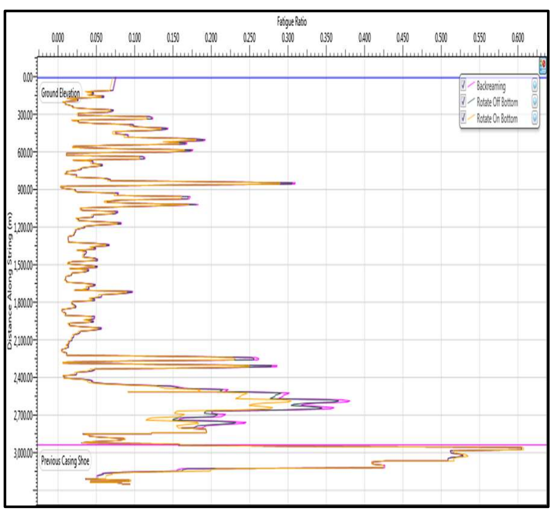


Figure 29: Fatigue Ratio Plot of drillstring 8 1/4" of Well-AG.

4. Conclusions

Application of torque and drag module in Abu Ghirab oilfield (Well-AG) has been conducted in this study using Landmark (WellPlan) software. This software is considered as qualitative leaps in the drilling engineering to simulate what happens with drillstring while various operations or activities in the wellbore. The results of this study indicate that:

1- When the inclination angle is increased above 76° and reached 88.2° in AG-Well, the drillstring buckling is supposed to be occurred with much higher WOB (compression force) requirement.

2- The effective tension values are indicate when buckling is induced. The studied well is closed to buckle at 2408 m (MD). At the same time it is beneficial for presenting the state of drillstring, when it is in tension or compression. Drillstring is converted from tension to compression at MDs of (2850m to 2967 m)

3- The minimum value of WOB that caused a sinusoidal buckling in 8 ¼ inch hole diameter are 17.24 tonne and 12.65 tonne during rotating and sliding operations respectively. Drillstring buckling can be occurred in sliding before rotating operation and this is the same with helical buckling.

4- It is necessary to obtain the friction coefficient based on actual well data. The calibration option in WellPlan software was used. Actual friction coefficient values were used in Well-AG during tripping in, tripping out and rotating off bottom operations to lead accurate results.

5- Landmark (WellPlan) software needs to be further developed in the topic of friction calibration because it contains only three operations; tripping in/out, and rotating off bottom, while the other operations; rotating on bottom, backreaming and slide drilling are not included in this option.

Acknowledgements

The authors would like to thank Landmark group in Iraq to get Landmark (WellPlan) software license and training on it at the premises of Halliburton Company. Also, I would like to say many thanks to staff of Missan Oil Company (MOC) for supporting me and their effort in providing me with regarding information which is required to complete my this paper.

Appendex A

Table A-1: Drilling Fluid Data.

Well	**Well-AG**
Mud Base Type	Water
Base Density (g/cc)	1.11
Rheological Model	Bingham Plastic
PV (mPa*s)	21.5
YP (Pa)	9

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Nomenclature

A	Azimuth (degree)
F_1	Axial force (drag) at the beginning of curved section with taking pipe stiffness into account (N)
F_2	Axial force (drag) at the end of curved section with taking pipe stiffness into account (N)
F_N	Normal force (Ibf)
F_X	Summing the forces in the x direction (Ibf)
F_Y	Summing the forces in y direction (Ibf)
M_1	The torque at the base of segment ΔL (ft-lbs)
M_2	Torque at the upper of segment ΔL (ft-lbs)
R	The radius of the pipe (inch)
T	Drag force (Ibf)
T_1	Tension at the base of segment ΔL (Ibf)
T_2	Tension at the upper of segment ΔL (Ibf)
W	Unit weight of the pipe (kg/m)

Greek symbols

α	Dogleg angle (degree)
ΔA	Change in azimuth over ΔL (degree)
ΔL	Pipe incremental length (m)
$\Delta\theta$	Change in inclination over ΔL (degrees)
μ	Friction coefficient (dimensionless)
θ	Inclination angle (degree)
θ_{avg}	Average inclination (degree)

Subscripts

1	Bottom of segment
2	Top of segment
N	Normal
x	X- diriction
y	Y- dirction

Abbreviations

AG	Abu Ghirab
Az	Azimuth
BHA	Bottom Hole Assembly
DDR	Daily Drilling Report
DLS	Dog Leg Severity
EW	Easting Coordinate
FWR	Final Well Report
Inc	Inclination
MD	Measured Depth
MDs	Measured Depths
NS	Northing Coordinate
OD	Out Side
POOH	Pull Out Of Hole
RIH	Run In Hole
ROFFB	Rotating Off-Bottom
TOB	Torque On Bit
TVD	True Vertical depth
VS	Vertical Section
WOB	Weight On Bit
WOC	Water Oil Contact

تحليل عزم الدوران والسحب في بئر ابو غرب الافقي باسخدام برنامج Landmark (WellPlan)

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نشر في: 31 كانون الاول 2021

الخلاصة – ان دراسة وبناء نموذج عزم وسحب قريب من الواقع أمرًا مهمًا للغاية للوصول للهدف بنجاح من خلال تحليل السلوك الميكانيكي لخيط الحفر وظروف تجويف البئر. عزم الدوران والسحب يحدثان عادة معًا فاثناء حفراي بئر معين فان تضيق تجاويف البئر ، انسلاخ الطفل ,استعصاء الانابيب في اخاديد في تجويف البئر ، الاستعصاء التفاضلي ، الاحتكاك مع تجويف البئر ، وتراكم القطع الصخرية المحفورة بسبب التنظيف غير الفعال لتجويف البئر كل هذه المشاكل تؤدي إلى زيادة مفرطة في عزم الدوران والسحب. في هذه الدراسة ، تم استخدام برنامج (Landmark software (WellPlan الخاص بشركة هاليبرتون في بئر مختار في حقول نفط ميسان وهو بئر-ابو غرب (حقل أبو غرب النفطي). تعد نمذجة عزم الدوران والسحب مهمة للتنبؤ بالنوافذ التشغيلية لخيط الحفر ,منها الشد الفعال ، الالتواء ، عزم الدوران ، التراخي والسحب ، الوزن على الحافرة ، ونسبة الوهن في خيط الحفر. تم استخدام ثلاث عمليات رئيسية في نمذجة عزم الدوران والسحب. أول عملية تضمنت استخدام بيانات الآبار المجاورة من البيانات الهرمية ,بيانات المسح , اعماق كل من البطانة و مقطع تجويف البئر المفتوح , مواصفات خيط الحفر ومجموعة قاع البئر, خصائص مائع الحفر , درجة الحرارة الجوفية ومعاملات العمليات التي تجرى اثناء الحفر.ان تصحيح وزن حمل الخطاف ، استخدام صلابة خيط الحفر واستخدام خيار المقاومة التي يسببها المائع للحركة الدورانية و السحب تم تضمينها في العملية الثانية. تتألف العملية الثالثة من معايرة معامل الاحتكاك باستخد ام بيانات حقلية حقيقية. تم دراسة عمليات الحفروالتي تضمنت سحب خيط الحفرمن تجويف البئر ، انزال خيط الحفر في تجويف البئر ، تدوير خيط الحفر بدون حركة محورية في حالة وجود وزن او عزم على الحافرة وفي حالة عدم وجودهما، تدوير خيط الحفر مع سحبه في نفس الوقت و الحفر الانزلاقي في مقطع تجويف مفتوح (8 ¼)بوصة. الاستنتاج الأكثر أهمية التي يمكن العثور عليه: عند زيادة زاوية الميل فوق 76° ووصولها الى 88.2 درجة ، يمكن أن يحدث التواء خيط الحفر مع متطلبات وزن على الحافرة (قوة ضغط) أعلى بكثير. البئر الذي تم دراسته يكون قريب على الالتواء عند العمق 2408 م (العمق مقاس). تم معايرة معامل الاحتكاك في برنامج WellPlan اعتمادًا على بيانات البئر الحقيقية لعمليات سحب خيط الحفرمن تجويف البئر ، انزال خيط الحفر في تجويف البئر و تدوير خيط الحفر بدون حركة محورية في حالة عدم وجود وزن او عزم على الحافرة.

الكلمات الرئيسية – عزم الدوران,السحب,الالتواء,معامل الاحتكاك,برنامج اللاندمارك.