Torque and Drag forces challenges in highly deviated oil well (Zubair oil field)

تحديات قوى عزم الدوران والسحب في الابار شديدة الميلان (حقل الزبير النفطي)

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Abstract:

The benefits from doing this analytical study in order to be able to measure and predict the frictional forces affecting a drill string and wellbore (Torque and drag) by construct model of well plan software, hence; the high deviated and directional wells must be planned to keep the torque and drag forces at a minimum and allowable limit.

Also, knowledge of the drill string phenomena can give us an opportunity to choose drill string components that consider these extra forces involved in the operations "high torque and drag values" in directional sections.

In addition to knowledge of influence torque and drag on planned well trajectory can give us a good idea and lesson learned to consider this challenges in the next planned well profile. As a result of well path design one of the best ways to reduce torque and drag forces.

One deviated well in Zubair oil field named, ZB-348 have been selected for analyses torque and drag problems and study the effect of (friction factor, well profile and drill string design) on the mentioned problem.

Well data include hole section size, fluid properties, well profile survey, rig specification, drill string details and drilling parameters were used in well plan software from landmark worldwide programming group to make a comparison between actual and planning status.

The results show a difference between planning and actual case when drilling 12.25" hole and found the root causes for this difference are high flow rate, tortuosity, well bore instability and complete losses.

The maximum torque about (20 klb-ft) and drag value approximately (30 klb)

Key words: Torque, Drag, Stuck pipe, Well bore instability.

Introduction:

Directional drilling represents a very important and famous to reduce drilling operations costs an oil field, this occur for the following concern:

1-Develop formation incoming when drill high deviated wells; hence, improve low permeability zones [1].

2-The cost of rig operations and mobilization will be minimized because of drilling more than well from same land or platform.

3-There are worldwide achievements to drilling high deviated wells instead of vertical wells due to some challenge limitations.

Facility of reciprocating and rotating drill string in directional wells and large well bores area represent the major concerns [1].

In spite of drilling high deviated wells have too much benefits, but still have many limitations along drill deviated sections. These difficulties must be controlled by engineering activities. As examples getting optimum drilling parameters become more difficult in deeper wells especially with complicated well profile. Two of these critical limitations called torque and drag that occur (cased or open hole) and drill string[1].

This type of drilling starts in Iraqi field about 2013 especially in Zubair Field, It is one of the largest oil fields in the southern part of Iraq.

the problems due to torque and drag were exit during drilling in this field like (stuck pipe, high drag value, losses or failure of drilling equipment) as a result increase NPT (non-productive time) period, so the analyses of this two factors have more benefits to design the well, minimize the drilling costs and prevent drilling equipment failure. Precautions must be get as immediate action to save torque and drag with optimum limits to avoid any formations or drill string failures.

Methodology:

Well Plan program [2] can define as drilling operation, completion activities and production service operations engineering programing. Well Plan software might be used at the office engineering work and well site activity to provide a tool to solve problems between engineering functions and oil field operations. Well Plan program is based on a database and data structure common to many of Landmark's drilling applications. This database is called the Engineer's drilling data model (EDM) and supports the different levels of data that are required to use the drilling software. This is a significant advantage while using the software because of improved integration between drilling software products.

The new results-oriented user interface offers more efficient analysis using only necessary inputs, saving time, and minimizing analysis steps.

Well Plan is integrated with the other EDT (engineering data training) applications enabling to install it on the same computer or server in multi-user environments, and share data with other EDT software applications.

The Torque and Drag program [3] can be used to expect the measured hook load weights and torques that can be phases while:

a- Running in the hole

b- Pulling out of the hole

c- Rotating on bottom

d- Rotating off bottom while pulling out of the hole

e- Sliding drilling without rotary table rotation

f- Backreaming after drilling

This calculation (output data) can be used to found if the well can be drilled, or to predict what is occurring within drilling the well. This module can be used for analyzing drill strings, casing strings, and liners.

Torque and Drag data base is depend on Soft String model as it is commonly known, in this model the drill string is deal similar to smooth cable without bending.

Friction force is assumed to effect in the opposite direction of drill string rotation and the buckling string forces desired are determined, in case of friction forces excess buckling limit the buckling phenomena is occurred, there are four types of buckling mode (transitional sinusoidal, helical, or lockup) are indicated [3].

Construction of well plan model:

Input data:

1- Datum information: for a land well

2- Fluids editor type: type of fluid and fluid properties like density, viscosity, yield point and yield strength.

3- Rig information: mechanical Limits including rig hoisting capacity and rotary torque rating, Circulating System, Rated working pressure for surface equipment, BOP pressure rating, Surface pressure loss, Mud Pit and Mud pumps specification.

4- Hole section editor: riser, casings and liner, open hole sections, friction factors for cased \ open hole sections, and annulus eccentricity.

5- Operation editor: select the analysis type and enter the parameters to be used in the analysis. The options available are:

a- Tripping In: need to enter the speed and RPM (revolution per minute) of the string.

b- Tripping Out: need to enter the speed and RPM of the string

c- Rotating on Bottom: need to enter WOB (weight on bit) and value of torque on bit.

d- Slide drilling: need to enter the WOB and value of torque on bit.

e- Back reaming: need to enter the value of over pull during the operation and the torque on bit.

f- Rotating off bottom: this operation does not require input parameters.

6- String editor: used to define the string component details like bottom hole assembly, drill pipe.

7- Subsurface properties editor: allows for defining pore pressure, fracture gradient, formation tops, geothermal gradient and formation influx.

8-Well path tab: vertical section, survey data imports and tortuosity are defined on the well path tab. Values for measured depth (MD), inclination (Inc) and azimuth (Az) must be entered for each row.

9- Tortuosity: in order to analyze a planned well path, may consider applying tortuosity to the well path to find the variation in actual well path trajectories.

10- Actual load values: the actual load is available on the analysis settings tab when viewing the following:

a- Friction calibration plot

b- Hook load plot

c- Torque point plot

Actual loads can be used to determine friction coefficients using the friction calibration plot and can be displayed on the Hook Load plot or torque Point plot to compare actual and calculated values.

11- Analysis Settings: to configure the analysis parameters settings pertaining to the outputs have added to the output area.

Two of the common setting is necessary especially in torque and drag analyses setting are:

a- Operational pump rate: the fluid flow changes the force and stress on the string.

b- Run parameters: these options allow specifying the depth of the bottom of the string at numerous intervals along the wellbore for the purpose of analysis.

These depths are used to generate output for the following torque and drag plots:

a- Hook load

b-Torque point

c-Minimum WOB

d-Friction calibration

e- Slack off \ pick up drag

Output data:

A listing of outputs for Torque and Drag analysis, use torque and drag tab to access plots and tables for torque and drag analysis.

These plots can show and calculate the possibility of drilling the well, in addition to indicate what the challenges while drilling the well will occur. Drill strings, casing strings, and liners can be analyzed.

Results and Discussion:

In order to analyses the results developed Torque and Drag model for this two forces and their effect on (friction factor, well path, string design),one case study data are examined, namely well ZB-348 [4], is part of Zubair Field Development Plan; its objective is to produce oil from Mishrif Reservoirs in the Middle part of the field, The well is planned as a deviated hole to a total depth of 2848 m MDRT (2481 m TVD RT).

The rig type that used to drill this well is land rig KCA, with 2000 HP, the contractor is Halliburton.

It was spudded on 2nd July 2016.It reached Section total depth on 1st September.

Hole size 12.25" had been drilled to 2442 m and 9-5/8" CSG set at 2437 m. production liner 8.5" drilled to 2762 m and 7" Liner set at 2757 m.

In this well, After finish drilling 12-1/4'' Hole to section TD at 2465 m with RSS BHA. It was difficult to Pump out the drill string so, it was decided to back reaming. The back reaming was very hard from bottom to 13-3/8''casing shoe at 1867m and faced many tight spots while reaming even in Saadi Limestone formation.

It was very clear that the hole condition was really complicated due to many reasons either mechanical or chemical stresses which induced the brittle Shale of Tanuma formation to be instable.

The action was run back freely on elevator to 2210m, tight spot observed at that depth (inside Saadi formation), Reamed down to 2222m, then RIH freely on elevator to 2314m. Reamed down from 2314m to 2370m with normal pressure and normal Torque. From 2370m to 2386m there was gradual increasing in pressure from 3080 psi to 3140 psi with the same flow rate and simultaneously the string slacked off from 103 ton to 97 ton.

All these indications refer to that there was Micro pack-off, and that Pack- off should be avoided and get away on the opposite direction (Pick up), otherwise it will improve to harmful pack-off.

As shown in Figures below (1) to (3) respectively as given in the Tables (1), (2) show the following output data hook load and torque value with different friction factor, allowable pick up and slack off drag without drill string failure, well path inclination with tortuosity and drill string analyses include minimum WOB to prevent buckling for plan and actual case.

1- Tripping loads analysis hook load 12.25" hole –klb- plan case Friction factor cased hole\open hole 0.4\0.5, block weight 50 klb, WOB 22 klb, flow rate = 3 m^3\min.

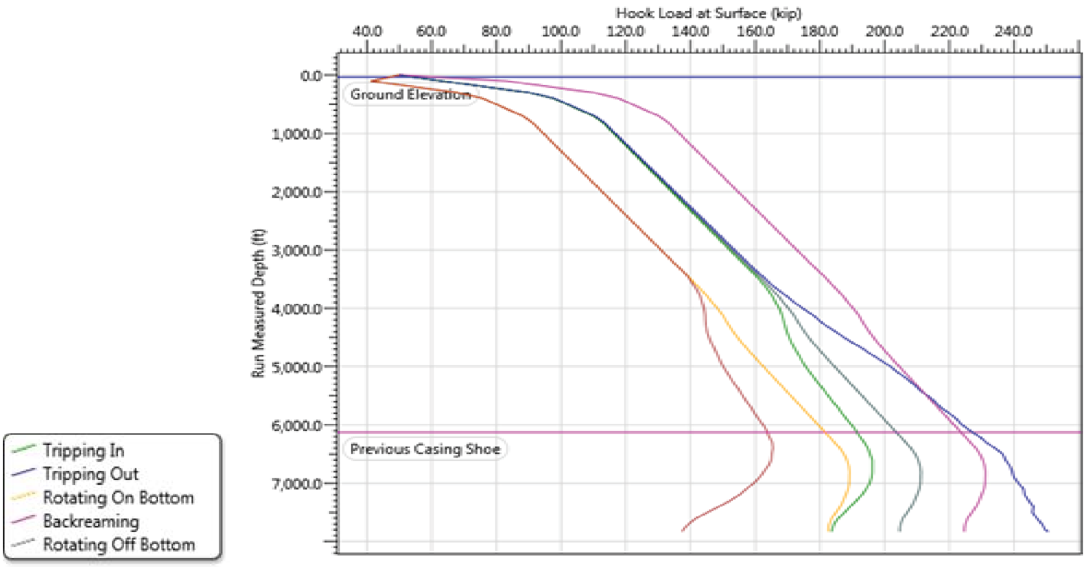


Fig. (1) Surface hook load weight VS MD for well zb-348

2- Surface torque 12.25" hole -lbf.ft-plan case FF - CH\OH 0.4\0.5, block weight 50 klb, WOB 22 klb , FR = 3 m^3\min.

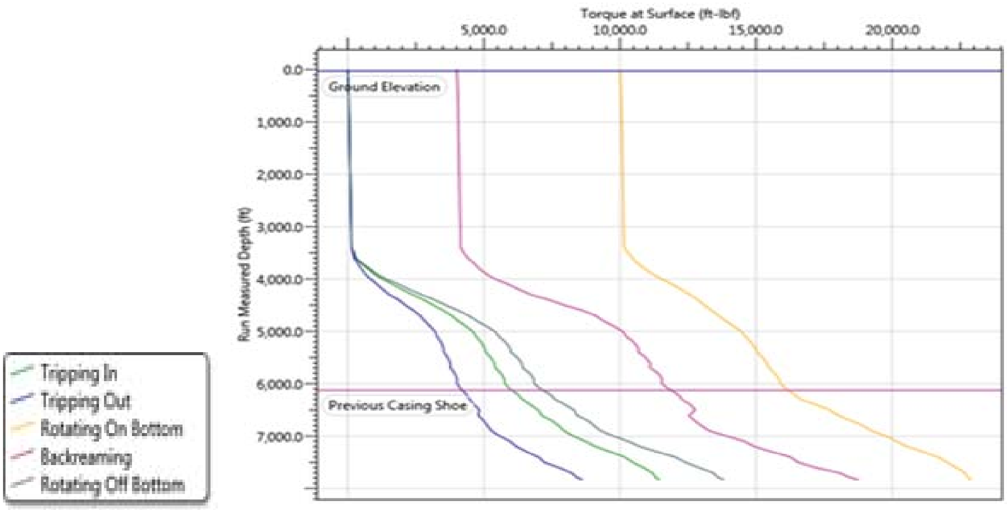


Fig. (2): Surface torque VS MD for well zb-348

3- Pick up and slack off weight 12.25" hole -klb –plan case FF- CH\OH 0.4\0.5, block weight 50 klb.

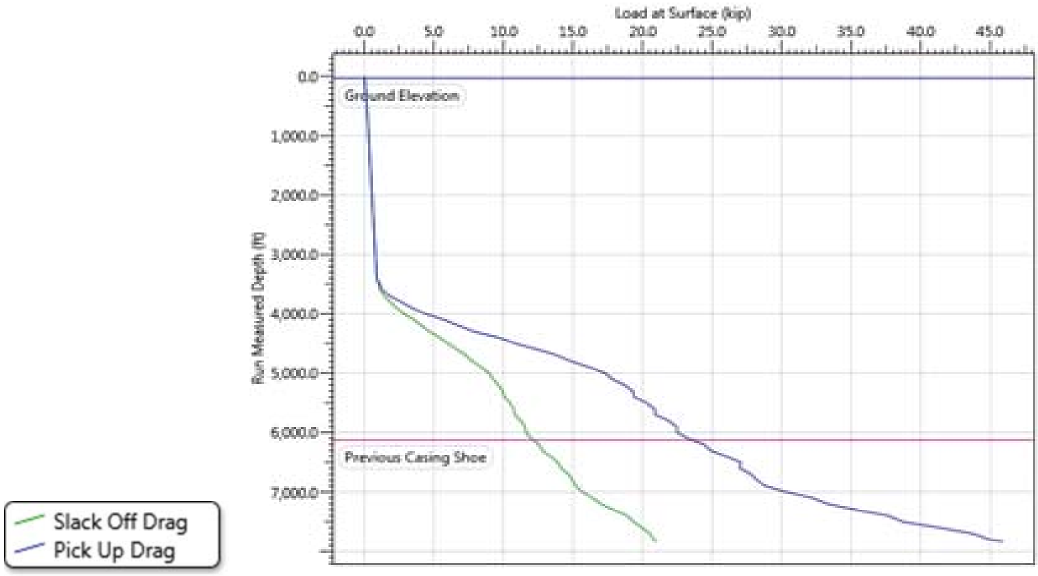


Fig. (3): Pick up and slack off weight VS MD for well zb-348

4- Tripping loads analysis hook load 12.25" hole -klb –actual case FF CH\OH 0.3\0.4, block weight 50 klb, WOB 22 klb, FR = 3 m3\min

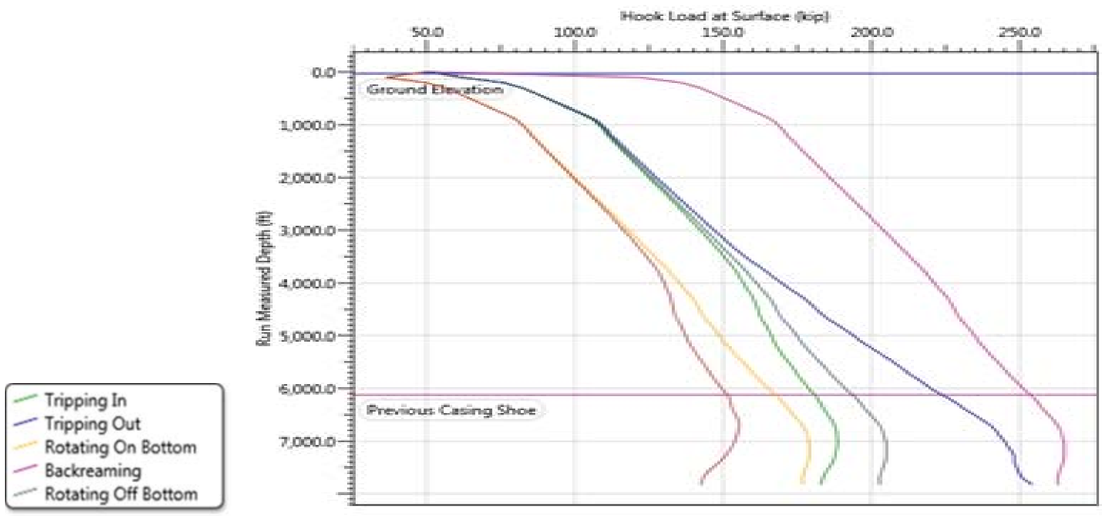


Fig. (4) Surface hook load weight VS MD for well zb-348

5- Surface torque 12.25" hole -lbf.ft- actual case FF - CH\OH 0.3\0.4, block weight 50 klb, WOB 22 klb , FR = 3 m^3\min.

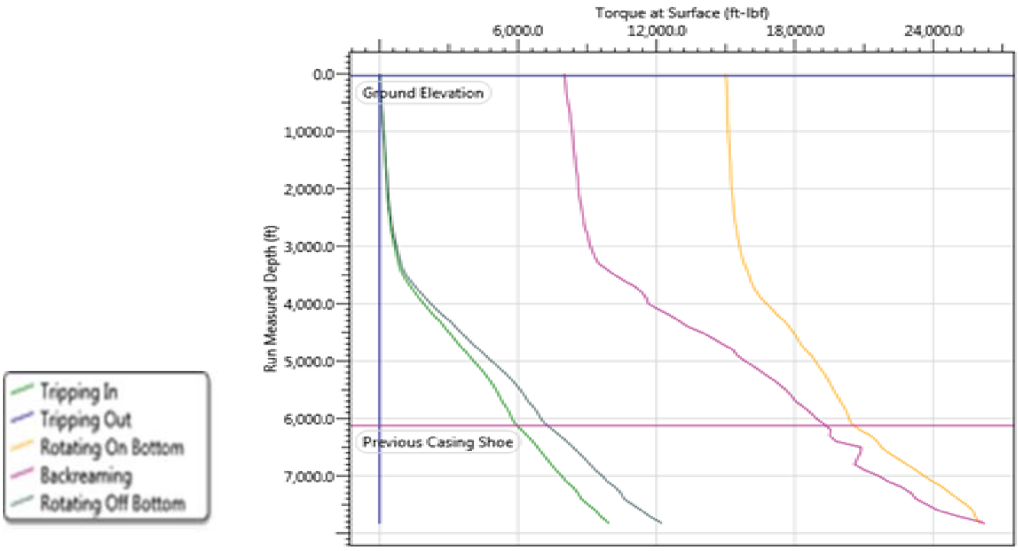


Fig. (5) Surface torque vs MD for well zb-348

6- Pick up and slack off weight 12.25hole –klb- actual case FFCH\OH 0.3\0.4, Block weight 50 klb

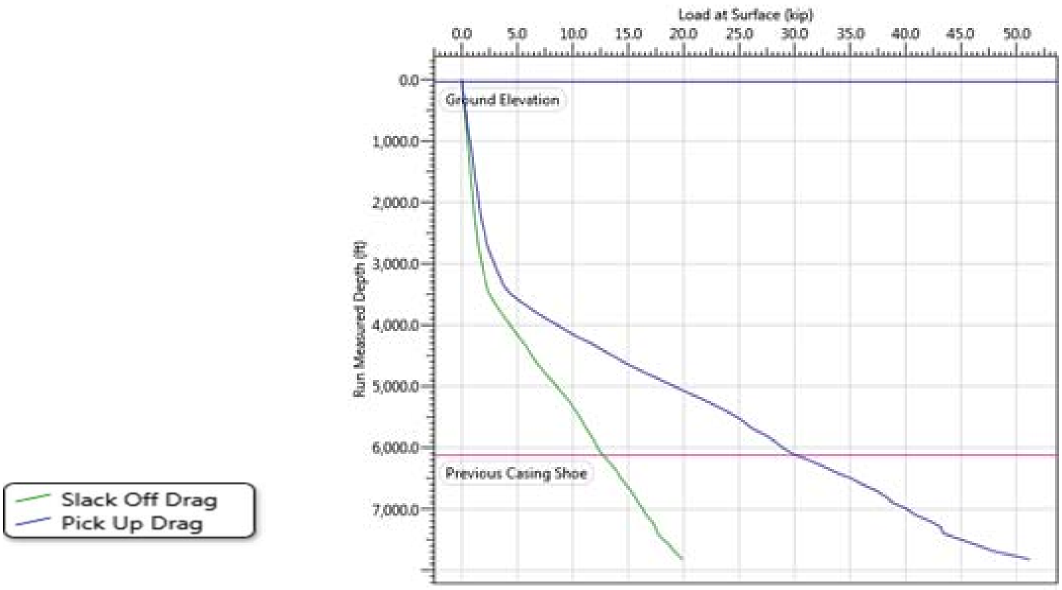


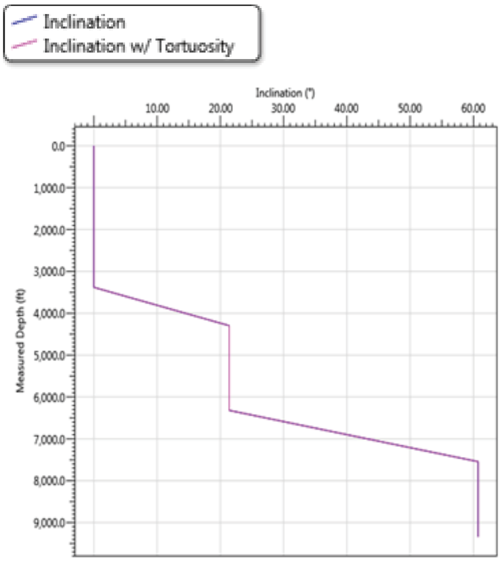
Fig. (6) Pick up and slack off weight VS MD for well zb-348

- As shown in Figures (1, 4) the tensile or compressive yield limit at each of the string depths analyzed, From the graph ,you can determine the load that will fail the work string in plan and actual case for well zb-348 (mishrif target) depending on drilling program (proposal) and final well report (results) for this well.
- This plots show that the surface hook load while tripping out and back reaming modes as compare with other modes due to open hole shape ,tortuosity and differential stuck pipe during hard back reaming and high over pull drag if compare with (tripping in, rotating on bottom, rotating off bottom and slide drilling).
- As shown in Figures (2, 5) the maximum torque found at surface for all rotary operating modes selected during specific depth interval.
- Increase RPM (revolution per minute) while tripping in and rotating off bottom will lead to increase torque chance, and this torque become zero while tripping out RPM =0
- Rotating mode has more torque as compare with sliding mode due to high friction force with rotation.
- High flow rate will increase torque especially with high friction factor for open hole.
- As shown in Figures (3, 6) pick up and slack off drag yield limit at each of the string depths analyzed should be not exceed during each rotating\sliding mode selected.
- In case of surface hook load weight is higher for back reaming and tripping out modes will increase pick up drag and got maximum value of drag when get stuck in buildup, hold and drop deviated sections.

- Caving, sloughing, swelling and thick mud cake in formation wall will give high pick up drag value as in Figure (6).

- Always should be observe the maximum yield strength and tensile strength for each drill pipe and bottom hole assembly within drilling and tripping operation.

7- Well path inclination with tortuosity – plan and actual cases



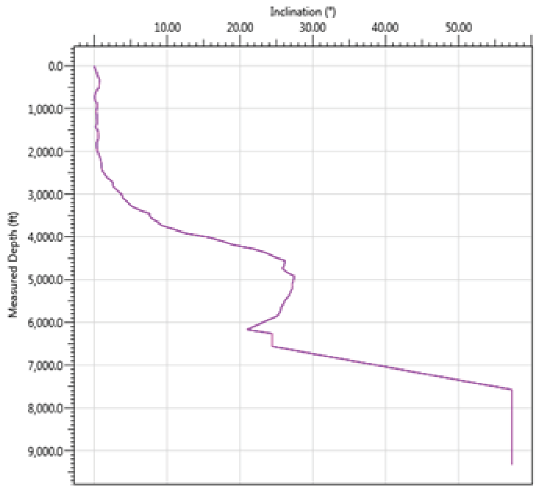


Fig. (7) Well path inc. w\tortuosity– plan

Fig. (8) Well path incl. w\tortuosity -actual

- As shown in Figures (7, 8) the variation of inclination angle along measured depth depending on plan and actual survey, in actual case can found higher kick off points (KOPs) and high hole curvatures actually increase torque and drag.

8- Drill string analyses - plan and actual cases

Table (1) Drill string analyses -well zb-348 – plan case

String Analysis

Minimum WOB (Rotating) to:
Sinusoidal Buckle **62.7 kip** begins at **6,282.2 ft**
Helical Buckle **70.6 kip** begins at **6,282.2 ft**

Overpull Margin (Tripping Out): **294.2 kip** at **90.00 % of yield**
Pick-Up Drag: **27.1 kip**
Slack-Off Drag: **13.9 kip**

Operation	Stress Failure			Buckling Limits			Torque Failure	Measured Weight (kip)	Stretch (ft)				Rotary Table Torque (ft-lbf)	Windup With Torque (revs)	Windup Without Torque (revs)	Axial Stress = 0 [From TD] (ft)	Surface Neutral Point [From TD] (ft)
	Fatigue	90% Yield	100% Yield	Sinusoidal	Helical	Lockup			Mechanical	Ballooning	Thermal	Total					
Tripping In								190.8	5.0	-0.9	0.3	4.4	7,221.1	3.0	3.0	745.2	0.0
Tripping Out								231.8	6.4	-0.9	0.3	5.8	5,096.2	2.1	2.1	509.4	0.0
Rotating On Bottom								182.7	4.5	-0.9	0.3	3.9	17,954.9	8.2	3.4	745.2	378.6
Slide Drilling								156.5	3.4	-0.9	0.3	2.9	9,000.0	4.4	0.0	745.2	1,476.1
Backreaming								224.7	6.3	-0.9	0.3	5.8	13,114.6	5.6	3.6	384.4	0.0
Rotating Off Bottom								204.7	5.5	-0.9	0.3	4.9	8,528.8	3.5	3.5	745.2	0.0

Table (2) Drill string analyses- well zb-348- actual case

String Analysis

Minimum WOB (Rotating) to:
Sinusoidal Buckle **59.9 kip** begins at **6,526.8 ft**
Helical Buckle **67.4 kip** begins at **6,137.6 ft**

Overpull Margin (Tripping Out): **263.4 kip** at **90.00 % of yield**
Pick-Up Drag: **51.2 kip**
Slack-Off Drag: **19.9 kip**

Operation	Stress Failure			Buckling Limits			Torque Failure	Measured Weight (kip)	Stretch (ft)				Rotary Table Torque (ft-lbf)	Windup With Torque (revs)	Windup Without Torque (revs)	Axial Stress = 0 [From TD] (ft)	Surface Neutral Point [From TD] (ft)
	Fatigue	90% Yield	100% Yield	Sinusoidal	Helical	Lockup			Mechanical	Ballooning	Thermal	Total					
Tripping In								183.1	5.1	-1.1	0.4	4.4	9,915.3	3.7	3.7	885.4	0.0
Tripping Out								254.2	7.2	-1.1	0.4	6.6	0.0	0.0	0.0	509.9	0.0
Rotating On Bottom								177.0	4.6	-1.1	0.4	3.9	26,027.7	11.5	4.2	885.4	665.6
Slide Drilling								142.5	3.3	-1.1	0.4	2.6	12,000.0	5.9	0.0	885.4	2,071.3
Backreaming								263.0	8.3	-1.1	0.4	7.7	26,227.7	10.2	6.3	242.3	0.0
Rotating Off Bottom								203.0	5.7	-1.1	0.4	5.0	12,219.7	4.4	4.4	819.6	0.0

- As given in Tables (1, 2) display all drill string limitation for rotating \ sliding mode, this tables can use for engineering work while string design and keep all drill string limitation in mind to make proper drill string design at any well conditions.

Conclusions:

1- The results were analyzed for 12.25" hole section based on the plots for plan and actual cases, the difference found between them due to several factors such as; friction factor, well profile tortuosity, cutting beds in annulus, well bore instability, higher kick off points (KOPs) and high hole curvatures, pack-off drill string, and unexpected torque and drag for 12.25"hole section.

2- The used model can be used by the oil field personnel to:

a-Calculate and predict torque and drag within rotating, tripping and sliding modes expected along complete measured depth interval.

b- Facility of check if drilling activities are progress with optimum torque and drag limitation further that must be double check for all drilling parameters can effect on this two factors, and allow to avoid potential risk on account of overabundance torque and drag value are expected.

c- Calculate reliable friction force can depend and use it for offset wells to avoid any torque and drag failure due to this factor.

d- Design rotating, tripping and sliding operations to ensure that drill string limitation proposed are not going to be exceeded while drilling operations.

e- Reduce and eliminate the operational risk of drilling horizontal and directional wells with complex well profile.

f- Reduce NPT (non-productive time), down hole drilling equipment's losses and consequently economic losses.

g- Provide a good response from rig personnel's about hook load data in case of hoisting and lowering of a drill string depending on model results.

3- The root causes for difference values of torque and drag for plan and actual conditions while drilling 12.25" hole; high flow rate, tortuosity and well bore instability; also the maximum torque and drag about (20 klb-ft & 30 klb).

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