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The Effect of Torque and Drag on the Drill String in Vertical and Directional Wells by Using Drilling Simulator

Mohamed Sobhi Ibrahim Elsayed [1], Taher El-Fakharany [2], Samir Khaled [2]

[1] Petroleum and Mining Department, Al-Azhar University, Faculty of Engineering, GANOPE, Cairo, Egypt
mohammedsobhy1992@yahoo.com

[2] Associate Professor of petroleum Engineer, Al-Azhar University/ Faculty of Engineering, Cairo, Egypt

[2] Associate Professor of petroleum Engineer, Al-Azhar University/ Faculty of Engineering, Cairo, Egypt

Abstract

Torque and Drag analysis are very important to ensure mechanical integrity of drillstring, it is necessary to predict the expected Torque and Drag on drillstring and then ensure that these Torque and Drag do not lead to failure of the drillstring. It is clear that Torque and Drag should be predicted as accurately as possible to allow safe, economical drillstring designs and complete well safely. This work shows the relationship between density, friction factor, number of heavy weight drill pipe, number of drill collar, revolution per minute, weight on bit, Direction tools and Torque & Drag in cased and open hole and how the hole geometry effecting on Torque and Drag by using drilling simulator. The procedures and options currently available for this evaluation are reviewed. The central role of torque-drag calculations in this evaluation is well recognized.

The Torque and Drag is still one of the important problems faced during drilling operations. In facts, the factors effecting on Torque and Drag are very complicated in directional wells. Some of them have been played much more attention to, but some of them a little. Several mechanisms may be involved, such as in-situ stress concentration, pore-pressure diffusion, plasticity, anisotropy, capillary effects and osmosis for shale, circle repeated load, thermal effects, and so on.

This work explains in detail how the Torque and Drag prediction by using drilling simulator will optimize the drillstring failure during the drilling operation. Where the total non-productive time was reduced with roughly 50% compared to earlier practice and leads also to complete the well safely to reach the target by working on greatest factor effect on Torque and Drag and recommend the best design for drillstring component which give the best optimizing for Torque and Drag using actual well case and also design new tool working on torque and drag reduction (Prototype available) and all above lead to cost optimizing with roughly 40% compared to earlier practice.

Keywords

Drilling tool, mechanical drag and torque reduction, vertical well, deviated well, density, friction factor, number of heavy weight drill pipe, number of drill collar, revolution per minute, weight on bit, Direction tools effect on torque and drag, new torque and drag reduction tool design.

1. Introduction

Torque and Drag optimization have developed from being related to conceptual optimization as the rotary drilling principle and the use of drilling mud in the 1920's, full automation of rig and mud handling in 1967 to the application of the first scientific techniques. The same techniques that make up the fundamental base for what Torque and Drag Optimization are today. So, through taking from C-K Chen which made in 2004 David C-K Chen defines drilling optimization based on this concept the Torque and Drag Optimization will be defined as:

"Torque and Drag optimization are a process that employs drilling parameter and surface equipment, computer software, down hole equipment and experienced expert personnel – all dedicated to reduce torque and drag trouble time and increase drilling efficiency"

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As the cost of lifting oil is growing, it is important to increase the drilling efficiency and reduce well construction time. A study of drilling in shallow water shelf in the Gulf of Suez shows that troubled torque and drag accounts for 30% of rig time. In dollar terms, it is about 1.5 million USD per well.

Hence, a small reduction in trouble torque and drag and also increased drilling efficiency can result in tremendous time and cost savings. On the Egyptian western and easterner desert there is in addition to the continuous battle to reduce trouble torque and drag a time squeeze developing.

It is claimed that Torque and Drag Optimization services increase ROP, reduce NPT and failures. However, it is very difficult to measure the exact effect Torque and Drag Optimization has on the drilling operations. This thesis aims to study the effect of important parameter has on the Torque and Drag Optimization.

Efficiency and time usage, and at best quantify the value of this effect. This is done by comparing the performance in 4 carefully selected Egypt wells.

The wells are analyzed in terms of the vertical and direction well that were spent in each hole section. In addition, the Rate of Penetration and Non-Productive time is evaluated. The drilling efficiency in each well and recommend the best design for optimum Torque and Drag.

The work will be done on drilling simulator and compared simulator result with actual result and the result evaluated and discussed in terms.

Literature review

Technical limit is defined as the best possible well construction performance for a given set of design parameters. The Technical limit approach is based upon the time used to construct a theoretical well where all operations are carried out without any flaws and without any improvement potential. This is done by;

- Selecting a set of appropriate reference wells
- Dividing the well construction process into sequences
- Quantify the time used in each sequence or section

The "best in class" time usage in each section / operation of the reference wells is added up to generate the total time used to drill the Theoretical well. As an analog, The Technical limit/ theoretical well is kind of aiming to set the world record or at least regional record in all ten aspects of a decathlon. Removable time is defined as the difference between the actual well duration and the technical limit time. Removable time is then divided into conventional lost or down time and invisible lost time. Invisible time being the classification of the activities that one would include in a normal well, like; wiper trips, mid-section bit change or BHA trips, reaming etc.

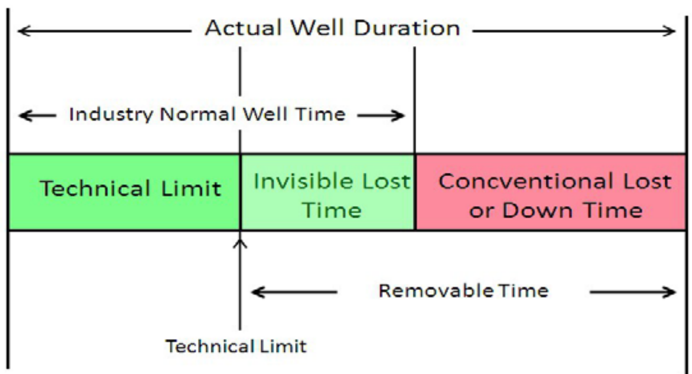

Figure 1 - Schematic showing the relationship between: Technical Limit, Invisible Lost Time, Conventional Lost or Down Time, Actual well duration and the industry normal well time.

Torque & Drag Reduction Method

To maximize possible target reach, it is important to apply all the possible torque and drag reduction techniques. This sub-chapter briefly summarizes the torque and drag reduction methods. In order to mitigate torque and drag forces engineers have developed various means. These methods may be listed as the following:

- Wellpath design
- Lubricants
- Light weight string components
- Hole cleaning
- Co-polymer beads
- Mechanical friction reduction tools
- Increased drill string and rig capability'

Drag is the function of the normal force, tubular movement and coefficient of friction. The torque value is also proportional to the normal force, coefficient of friction, drillstring configuration radius and tubular movement. By reducing any of the mentioned components will lead to a reduction of a torque and drag value'.

Efficient hole cleaning can eliminate problems with cutting accumulation and remediate high torque and drag in the wells. In directional well, hole cleaning may be quite challenging and therefore must be carefully planned for each well section. The efficient cutting removal failure could lead to a significant torque and drag increase and without successful attempts to mitigate it, to even more severe operational problems such as drillstring stuck.

In order to decrease normal forces in a wellbore, the high buoyancy can be beneficial as it will limit the load on the drillstring. However, the disadvantage of a dense fluid is the fact that high particle size in the mud. low friction in the wellbore can also be obtained by using drilling mud additives.

By using mechanical devises and lubricants for a given well path and borehole condition the torque and drag values could be significantly reduced. Different types of such mechanics can be installed between the connections or directly on the pipe. Most widely used in the industry are rollers and non-rotating sleeves. Presence of these components on the drillstring will assist drilling and running operations by increasing available weight and decreasing slip stick effect". As the general recommendation during the drilling directional well is to use low weight drill pipe and BHA. This will reduce tension and increase buoyancy, leading to low friction.

The Torque & Drag optimization Elements

The torque and drag optimization process have 4 main focus points: Drillstring integrity, Drilling Parameter, Hole Trajectory and Friction Factor.

Drillstring integrity

Drill string integrity focuses on the prevention or reduction of mechanical overload, protection from fatigue and minimizing excessive shock and vibrations. The most important issues are downhole vibrations like BHA buckling and torque & drag. Specialized computer software (Drilling Simulator) provides torque and drag modeling.

Actual drill string design run on (Drilling Simulator) allow to measure harmful force modes and identify active torque and drag mechanisms. Change BHA drilling like (No. D/C, No. HWDP, RSS OR MTR) enables corrective actions to be taken to reduce damaging and select the best design.

Drilling parameter

Drilling parameter focuses on keeping the hydrostatic and dynamic pressures between critical upper and lower operating limits, optimizing circulating pressures, hole cleaning and clean-up cycles, optimizing ROP and tripping speed without exceeding the pressure limits.

This is done by the simulator models for Torque & Drag to predict the effect of change drilling parameter WOB, RPM and direction tool on Torque & Drag.

Based on change drilling parameter have different result for Torque & Drag and the best recommendation will be done.

Hole Trajectory

In hole trajectory the Torque & Drag optimization process concerns about designing the best well pass.

Through joint working on simulator discovered that the hole trajectory plays fundamental role for optimizing Torque & drag in the planning stage.

Friction Factor

Through joint working on simulator found that Friction factor is very critical and also great factor effecting on Torque & Drag in all types of wells, the friction factor is independent factor and depending only on contact force between drill string and well bore.

So, and based on simulator result the decision was taking working on reduction friction factor by reducing contact area between drill string and well bore.

Data sources and systems

Actual drilling well data

- **LWD measurements**

  Sonic, density, resistivity, Formation-Pressure While Drilling FPWD, LWD imaging tools and seismic while drilling - SWD, significantly improve the quality of the optimization services.

- **MWD measurements**

  - Downhole Annular pressure, Bore Pressure and temperature measurements - supplied by the PWD tool. Used in all analysis in all three elements of the DO
  - Borehole dimensions – supplied by acoustic caliper tools, provide a detailed image of the borehole wall, increases accuracy of wellbore volume calculations
  - Downhole vibrations – Supplied by vibration sensors like DDS, gives Average, Peak and Burst (instantaneous) vibration readings along all three axes provides information on loads of equipment and vibration mechanism.

Surface Data-logging Parameters

SPP (Stand Pipe Pressure), TT (Trip Tank) and pit volumes, Flow in/out, gas levels, block height, RPM, depth, WOB, Hookload, Surface torque.

2. Methodology

Case study by drilling simulator for four verticals well and four directional well

Drilling Facilities

It was decided that the wells had to be drilled from the same drilling facility. This will remove the factor with different capabilities and specifications related to each drilling facilities. It would also remove to some extent the human skill factor, as this would keep the same people rotating the rig and thereby the wells would be drilled with people from the same skill pool. The differences between each crew would still be present, but it was considered as an impossible task to remove this element.

Well trajectory

The well trajectory is a major factor when it comes to the technical level of the drilling operation. Inclination, turns and dogleg's due to a large extent have an impact on the difficulty of Torque & Drag mitigation. It was therefore considered important to consider wells with more or less the same level of difficulty when it comes to well trajectory.

Hole section

There will be different challenges in different hole sections. In the 17 1/2" hole section one need to take special concern about the level of consolidation of the formation, however this does not usually introduce the same level of concern in the 12 ¼ Section. The performance study in each well will therefore to a large extent be section like.

Geo-Technical aspects

There are a lot of different challenges related to drilling into the subsurface. Different formations may or may not have facilitated special conditions or properties which make them easier or harder to drill. This is a highly analyzed and debated theme and it was therefore made an effort

to select wells that was drilled in the same field and not too far from each other. In addition to the well trajectory criteria, this suggests that the general lithology the wells are encountering will to some extent possess the same properties and thereby introduce the risk for the same challenges.

Torque & Drag Optimization services

The idea behind the study is to try to quantify the value of Torque & Drag optimization. It was therefore imperative that the wells that were studied had been subject and exposed to the same level of Torque and Drag optimization services.

Source of Information

The well study covered all Egypt Fields and involved different drilling facilities, permanent as well as mobile. The End of Well Reports made by the Directional Drilling, Measurements while drilling, Surface data logging and Advanced Drilling Technology service lines and the operator company's drilling program were used as the source of information in the study. eight wells were selected and considered appropriate for comparison. These wells will be referred to as well #1 - #4 in further discussion.

Planning

Torque & Drag simulations was carried out with regards to: Helical buckling – rotating, Helical buckling – Non Rotating, Sinusoidal Buckling – all operations, Slide Drilling, Rotation on bottom and tripping out.Critical rotary speed analysis was performed based on the planned BHA design.

Hydraulics simulations on circulation pressure, shear rate and shear stress were done based on BHA and drillstring design.

Study the effect of changing parameter such as WOB, RPM, DC, HWDP, Density, Friction Factor and direction tool on Torque & drag, recommend the best design based on Torque & Drag simulation result, delineate the greatest factor effect on Torque & drag and suggestion solution for reduce this parameter effect.

Optimization

The same optimization services and recommends the best design were applied to all wells. However, after delineate the most factor effect on Torque & Drag. This information was used to further improve the performance Torque & Drag by working on reduction this factor.

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Well trajectory

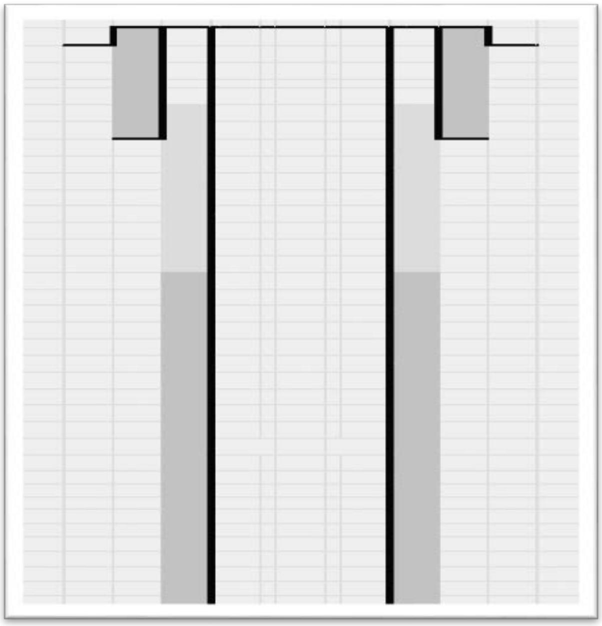

Figure 2 - well Trajectory of w8ell #1

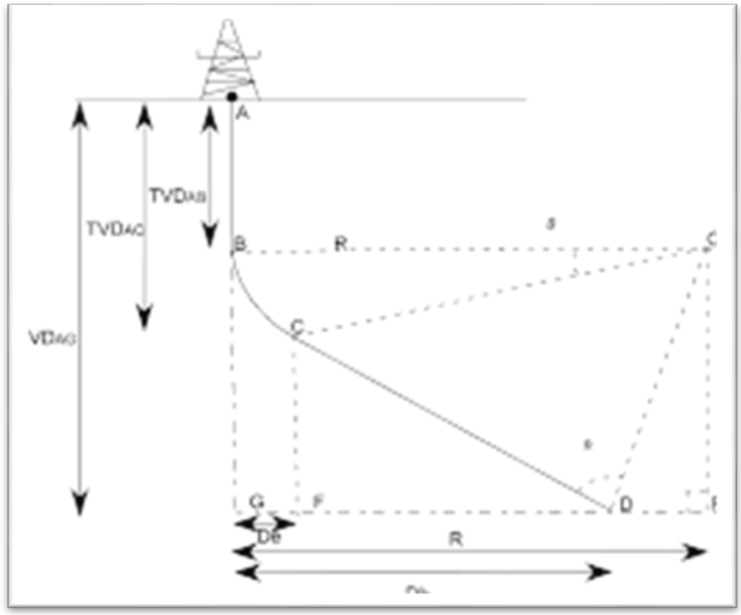

Figure 3 - well Trajectory of well #2

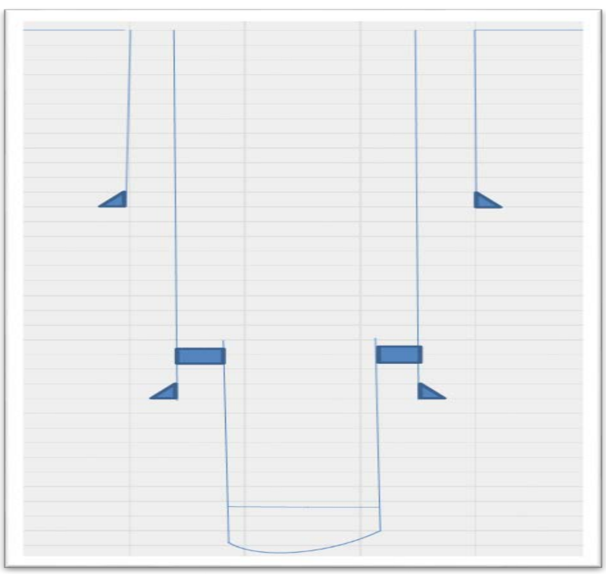

Figure 4 - well Trajectory of well #3

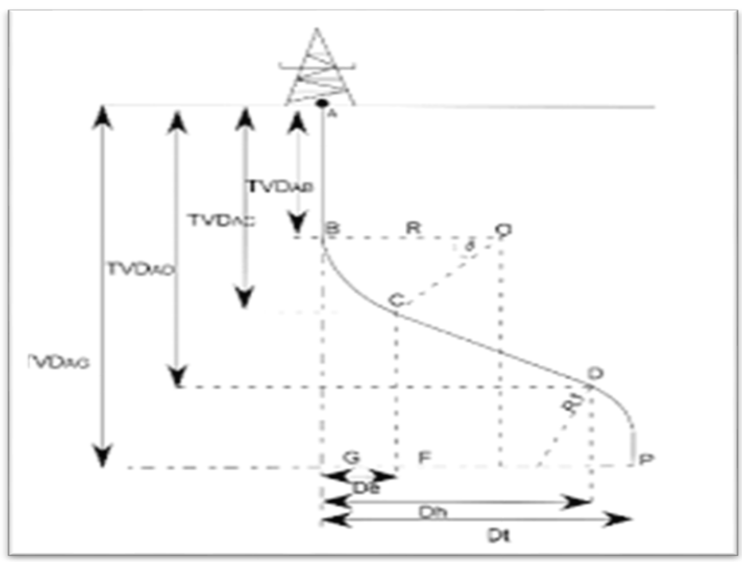

Figure 5 - well Trajectory of well #4

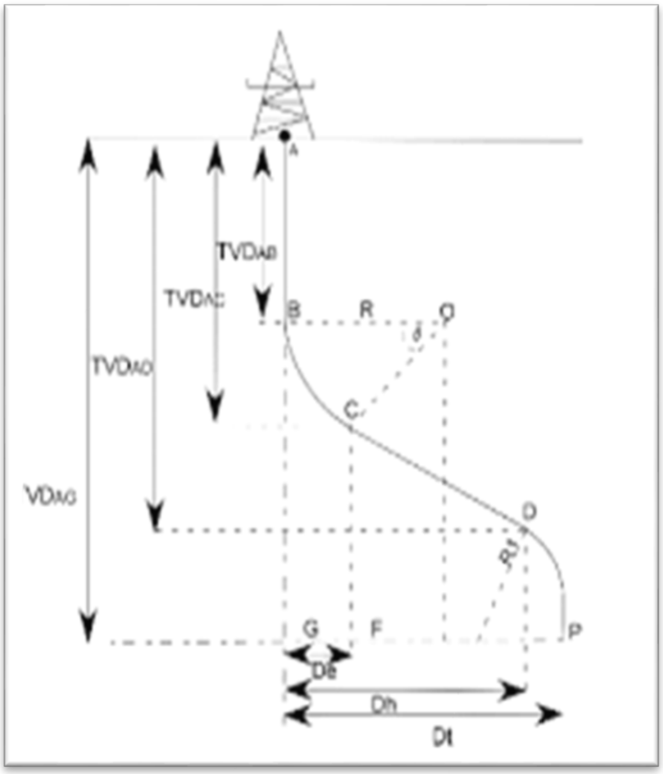

Figure 6 - well Trajectory of well #5

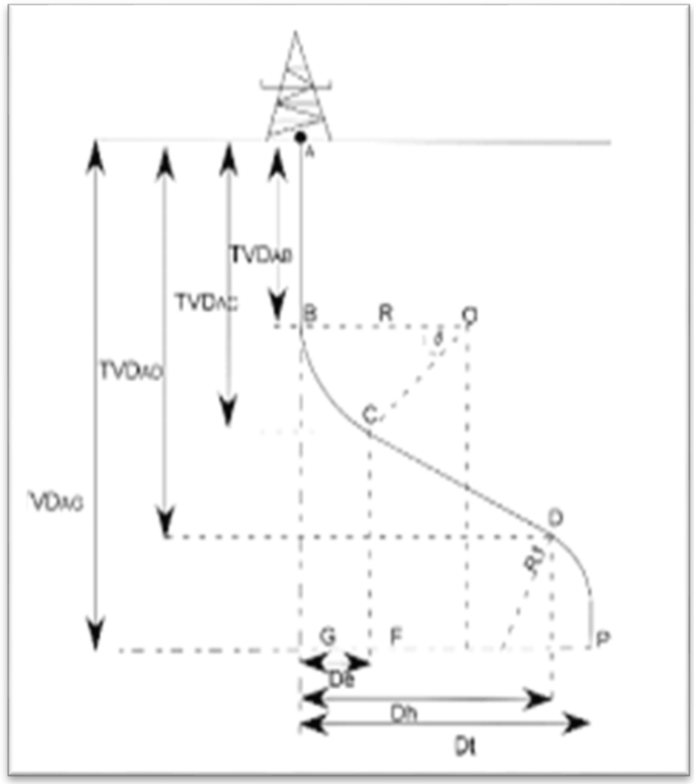

Figure 7 - well Trajectory of well #6

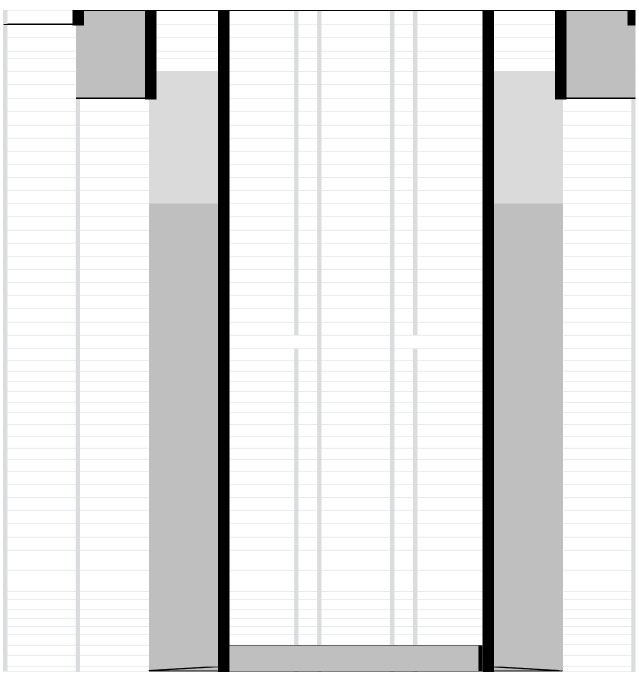

Figure 8 - well Trajectory of well #7

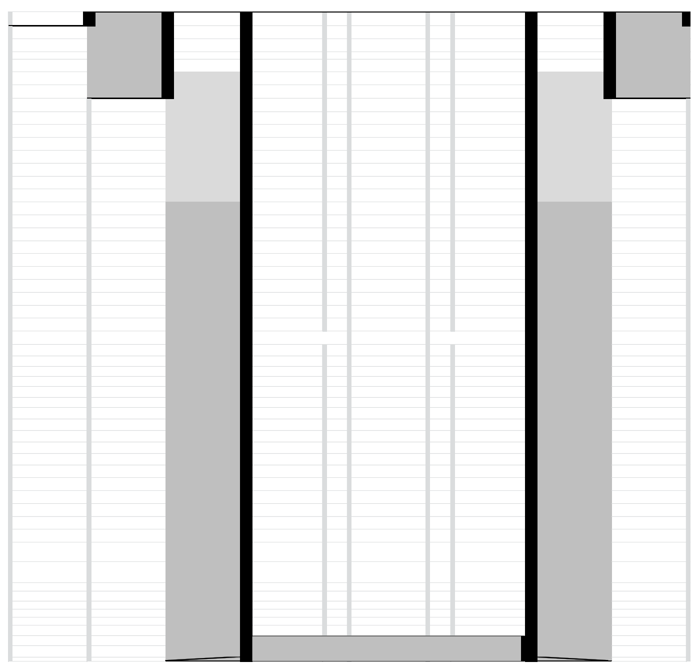

Figure 9 - well Trajectory of well #8

Performance Targets

As mentioned, the Torque & Drag is added to the well construction process when the total time used to drill a well is reduced. This is because the biggest and primary cost driver is related to keeping the rig in operation. The total cost of the rig including all additional services is the rig spread- rate. To see the real value of the Torque & Drag optimization one need to look at how much time is saved and reach to planed final depth by recommendation the best BHA design for Torque & Drag optimization process emphasis and also discovering new technique for optimization Torque & drag .The following section describes the parameters and target that have been used in the performance development study.

Parameters

SOW – Slack Off Weight is measured in [Kip] and is the weight of string when RIH without rotation.

PUW – Pick Up Weight is measured in [Kip] and is the weight of string when POOH without rotation.

ROT.W – Rotation Weight is measured in [Kip] and is the weight of string when POOH with rotation (Off BTM).

DRILL. W – Drilling Weight is measured in [Kip] and is the weight of string when RIH with rotation (On BTM).

ROT. T (Off Bottom Torque) – Rotation Torque is measured in [N.M] and is the resistance force of string during rotation off bottom.

DRILL.T (On Bottom Torque) – Rotation Torque is measured in [N.M] and is the resistance force of string during rotation on bottom.

Targets

To study the performance the following targets was used:

Density

Friction Factor

No. HWDP

No. Drill Collar

Drilling Direction tool

RPM & WOB

How to Interpret the Target Definitions

Working on above parameter and look at the result, finally make conclusion and work on the greatest factor for optimization Torque & Drag.

3. Results

This chapter presents the results from the performance study from the selected wells. The results are briefly described and will be further evaluated and debated in the discussion chapter of the thesis. The analysis has been carried out on each variable. The performance targets used are as described in the previous chapter. Each well represents each performance target with one value for each variable.

Density

Vertical Well

Through joint increasing density with same rate and other parameters keep it constant lead to decrease drag slightly and also decrease torque with same rate.

Deviated Well

Through joint increasing density with same rate and other parameters keep it constant lead to decrease drag slightly and also decrease torque with same rate.

Friction Factor

Vertical Well

Through joint increasing friction factor in cased and open hole with same rate and other parameters keep it constant lead to increase drag with highly rate and also increase torque with highly rate.

Deviated Well

Through joint increasing friction factor in cased and open hole with same rate and other parameters keep it constant lead to increase drag with highly rate and also increase torque with highly rate.

RPM & WOB

Vertical Well

Through joint increasing RPM & WOB with same rate and other parameters keep it constant lead to drag remain constant and also decrease on bottom slightly and off bottom torque remain constant.

Deviated Well

Through joint increasing RPM & WOB with same rate and other parameters keep it constant lead to drag remain constant and also decrease on bottom slightly and off bottom torque remain constant.

No. HWDP

Vertical Well

Through joint increasing number of heavy weight drill pipe with same rate and other parameters keep it constant lead to increase drag very slightly rate and also increase torque with same rate.

Deviated Well

Through joint increasing number of heavy weight drill pipe with same rate and other parameters keep it constant lead to increase drag very slightly rate and also increase torque with same rate.

No. DC

Vertical Well

Through joint increasing number of drill collar with same rate and other parameters keep it constant lead to increase drag very slightly rate and also increase torque with same rate.

Deviated Well

Through joint increasing number of drill collar with same rate and other parameters keep it constant lead to increase drag very slightly rate and also increase torque with same rate.

Direction tool

Through joint change direction tools using in drilling well and other parameters keep it constant lead to select the best direction tools based on torque and drag result and prove that the strong relationship between well trajectory and torque and drag.

Summary

Table 1- Summary for Variable Effect Result

Parameter	Drag	Torque
Increase density	Decrease ↓	Decrease ↓
Increase friction factor	Increase ↑	Increase ↑
Increase RPM & WOB	Slight Effect ↔	Decrease ↓
Increase No. HWDP	Increase ↑	Increase ↑
Increase No. DC	Increase ↑	Increase ↑
Direction tool	Select based on Torque and drag which tie on with trajectory of the well	

4. Discussion

The effect of change Variable on Torque & Drag

The effect of variable drilling parameter and bottom hole assembly on torque and drag are very critical and important, one will naturally improve the efficiency and performance of the operation. In this case, the same operations are performed and the well design is more or less the same. The variable effect should then be seen as a continuous improvement for each new well drilled.

With respect to Torque & Drag this improvement should give optimum drilling. The drilling circulation and operational hours used per length unit should decrease, as long as no other events influence the parameters.

Thee variable is variety and will check if the parameter is independent or so work on it to reduce torque and drag or the parameter is dependent so there is a short narrow to work on it.

Density

The density is very critical parameter, it is like a blood for well, the density tie on hole stability which connecting with type of formation, so the density is independent parameter and if there is any change in density hole stability will take in consideration, so any trial to reduce torque and drag through density depend on hole stability.

Friction Factor

Friction Factor is very important parameter, friction factor is independent and it is not tie on other parameter, the only factor effect on friction is well trajectory which impact on contact force between wall of the well and drilling string, the result show that friction factor is the greatest factor affecting on torque and drag so the further work in conclusion will work on reduce contact force between wall of the well and drilling string through design tool installed between joint of drill string to reduce torque and drag.

RPM & WOB

Revolution per minute and weight on bit drilling parameter is very essential parameter, the revolution per minute and weight on bit tie on down hole vibration, so the revolution per minute and weight on bit is not independent parameter and if there is any change in revolution per minute and weight on bit the other stresses will take in consideration, so any trial to reduce torque and drag through revolution per minute and weight on bit depend on other stresses.

No. HWDP

Number of heavy weight drill pipe tie on drill string design, so it is not independent parameter and if there is any change in number of heavy weight drill pipe the other stresses will take in consideration, so any trial to reduce torque and drag through number of heavy weight drill pip depend on drill string design stresses.

No.DC

Number of drill collar tie on drill string design, so it is not independent parameter and if there is any change in number of number of drill collar the other stresses will take in consideration, so any trial to reduce torque and drag through number of drill collar depend on drill string design stresses.

Direction tools

Every day there is new technology in direction tool but stay the hole trajectory is the important parameter effect on torque and drag and direction tool only help to reach target easily and do not have great effect on torque and drag.

5. Conclusion

The Value of torque and drag optimization has been studied by using drilling simulator and end-of-well-reports from 8 wells from the different type region in Egypt. The studied wells were covered of all type of well vertical and direction containing performance incentives. The incentives affected both the drilling service provider and the rig contractor.

The value of torque and drag Optimization has been studied, but it was not possible to quantify the effect of torque and drag optimization as per variable change. The source of the improvements could not be clearly identified but the study still visualized valuable elements both regarding the development in total drilling efficiency and displays key elements related to the process of optimizing the drilling efficiency:

- The optimization often gets camouflaged by other events affecting the performance targets.
- The well reports need to have a high(er) level of consistency and detail regarding the performed actions and improvements to reduce the uncertainty and allow identification of the different improvement measures.
- The greatest factor effect on torque and drag is friction factor.
- The study needs to apply on higher number of well
- Contract Incentives affects performance - Increased performance does not come for free and needs to be encouraged through contract incentives that impact all parties involved.
- The study further suggests that using MSS it is tool like stabilizer) between the drillstring joint and mainly in open hole section in deviation well to reduce contact force between drillstring and wall of the well and also centralize the drillstring in well.
- To assure future success of drilling, operator companies and oil companies need to reduce well construction time, and a Total approach to torque and drag Optimization, as the processes and measures described in this thesis, may facilitate the required measures for future success.
- The MSS New tool between drillstring joint is magic solution for torque and drag optimization and need to apply on actual condition to prove that, the design figure will be available below.

Advantage of new torque and drag reduction tools (prototype available):

- Control Directional Behavior
- Concentrate the BHA weight on the drill bit
- Minimize Bending and Vibration Damage
- Reduce Torque and Drag by Limiting Wall Contact
- Helps Prevent Differential Sticking and Key Seating
- Smooth Hole geometry

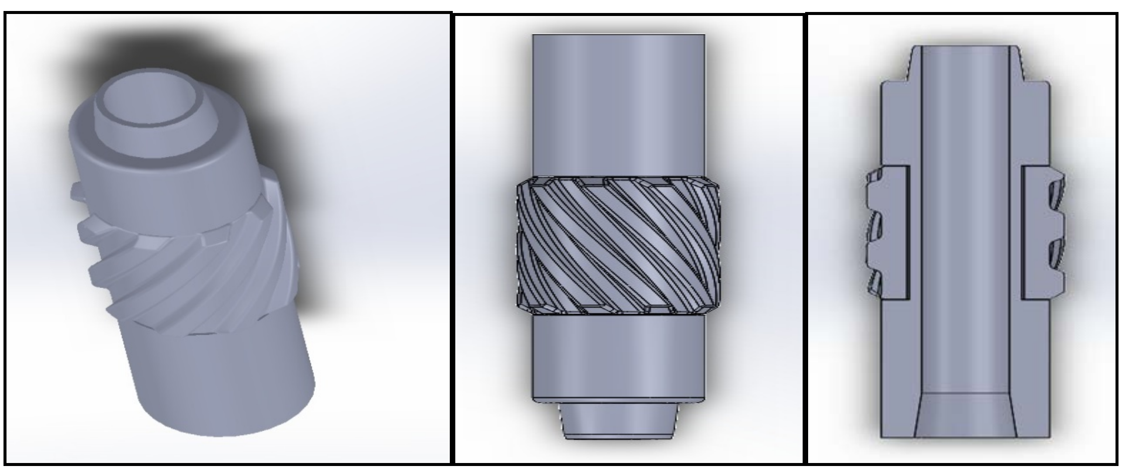

Figure 10 – MSS new tool design

Market survey for Torque & Drag Optimization down hole tool limitation:

Table 2 – Market survey for Torque & Drag Optimization down hole tool limitation

Market survey for Torque & Drag Optimization down hole tool limitation						
Contractor Name	*Torque Reduction %*	*Mechanism*	*Blade type*	*Hole type*	*Side Force Resistance lbf*	*Remarks*
Paradigm Drilling Services	*25 - 40*	*Bearing With Mandrel*	*Rubber*	*Cased hole mainly*	*10,000*	*limited*
Frank's International (DSTR)	*30 - 40*	*Bearing With Mandrel*	*alloy*	*Cased & Open*	*14,000*	*limited*
Halliburton	*25 - 40*	*Bearing With Mandrel*	*alloy*	*Cased & Open*	*15,000*	*limited*
Non Rotating drill pipe protector	*15 - 25*	*centrlizer*	*Rubber & Alloy*	*Cased hole*	*5,000*	*limited*
New torque and drag reduction Tools	*70 - 90*	*free rotation*	*alloy*	*Cased & Open*	*50,000.00*	**Easy To Use *Less Maintance *Higher Efficieny *High operation durability * less capital cost *Work on T &D * Have multiple function & advantages*

List of sample figure & Table
Well #1

1 Well #1 Variable Effect

Through joint changing the value of Parameter and look at the result, the calculation starts with actual condition then go changing.

Input Data

Hole Section

Table 3 – Hole Section Well #1

Type	OD	ID	Weight	Top	Bottom	FF
	[in]	[in]	[lb/ft]	[m]	[m]	
Open hole		8 1/2		740.67	1400.56	0.3
Casing	9 5/8	8.68	47.00	0.00	740.67	0.2

BHA

Table 4 – BHA Well #1

Type	Size	Nom Weight	Length	Body		Mtr	Grade (YS)	Class
				OD	ID			
	[in]	[lb/ft]	[m]	[in]	[in]		[psi]	
BIT	8 1/2		0.25	8.500				
Sub	6 3/4	97.72	5.58	6.750	3.000	CS	110000	
Stabilizer	8 3/8	93.72	1.52	6.250	2.000	CS	110000	
1X6 3/4"Drill Collar (MONEL)	6 3/4	93.54	8.91	6.750	3.250	CS	55000	
Stabilizer	8 3/8	93.72	1.52	6.250	2.000	SS	110000	
Sub	6 3/4	97.72	0.80	6.750	3.000	CS	55000	
2X6 1/2"Drill Collar	6 1/2	91.76	89.52	6.500	2.813	CS	135000	
Jar	6 1/2	85.89	4.97	6.500	2.250	CS	55000	
10X6 1/2" Drill Collar	6 1/2	91.76	18.33	6.500	2.813	CS	110000	
18X4 1/2" Hevi-Wate DP	4 1/2	39.80	165.42	4.500	2.813	CS	55000	
Drill Pipe	4 1/2	22.82	1103.74	4.500	3.500	CS	55000	P

Drilling Parameter

Table 5 – Drilling Parameter Well #1

Density	W.O.B	RPM	ROP
[PPG]	[Klb]	[rpm]	[ft/hr]
9.70	30.00	120.00	60.00

Survey

Table 6 – Survey Well #1

MD [m]	Inc [deg]	Azi [deg]
1400.56	1.05	132.49
1325.61	0.96	124.3
1306.402	1.06	130.27
1287.805	1.25	136.92
1268.598	1.45	154.08
1249.39	1.14	170.08
1230.183	0.92	173.25
1211.28	0.64	201.1
1192.378	0.55	250.31
1173.171	0.57	301.79
1154.268	0.39	317.27
1134.756	0.4	279.54
1115.549	0.57	240.13
1096.646	0.41	202.42
1077.439	0.35	163.17
1058.537	0.38	127.49
1039.634	0.4	72.54
1020.427	0.36	41.65
1001.829	0.26	347.92
982.622	0.27	268.01
963.7195	0.45	209.83
944.5122	0.55	196.56
925.3049	0.59	172.85
906.0976	0.73	140.6
886.8902	0.7	103.33
867.6829	0.53	51.4
848.7805	0.21	329.67
829.878	0.18	229.2
810.9756	0.34	207.19
792.0732	0.42	186.69
772.8659	0.4	155.53
753.6585	0.41	127.34
717.0732	0.1	321.25
699.6951	0.08	28.61
680.4878	0.15	44.06
661.5854	0.23	41.66
650.52	0.22	41.65
642.378	0.25	41.79
623.1707	0.23	32.18
604.2683	0.21	33.86
585.3659	0.11	116.28
566.1585	0.28	217.01
547.2561	0.52	219.97
528.0488	0.5	214.56
509.1463	0.5	214.29
489.939	0.45	199.63
470.7317	0.28	158.03
451.5244	0.27	167.11
432.622	0.29	158.37
413.4146	0.19	144.02
394.8171	0.11	155.27
375.6098	0.06	164.82
356.4024	0.06	174.88
337.5	0.11	169.25
318.5976	0.13	162.13
290.5488	0.19	164.88
272.2561	0.27	123.71
253.6585	0.33	102.77
235.3659	0.21	129.09
216.7683	0.32	112.95
198.1707	0.29	71.78
179.878	0.47	54.37
161.2805	0.07	105.37
142.6829	0.29	166.48
124.3902	0.19	157.27
107.9268	0.3	103.24
89.93902	0.03	170.29
71.95122	0.15	174.63
54.26829	0.19	141.64
36.89024	0.2	64.9
0	0	0

Out Put data

Density Variable

Table 7 – Density Effect Well #1

Well-1								
Condition	Density [PPG]	SOW [Kip]	PUW [Kip]	ROT [Kip]	DRILL [Kip]	Drag [Kip]	ROT [daN*m]	DRILL [daN*m]
Recommend	9.7	131.2327079	140.4199184	135.6994595	105.6860774	9.187210497	165.3868932	420.1097293
Variable	12	125.4066287	134.1662355	129.6653171	99.65299364	8.759606755	157.6678458	412.7169037
	14	121.0727306	129.5061879	125.1727779	95.16125266	8.433457371	151.7895882	407.1331566
	16	116.7393545	124.8466933	120.6807759	90.67003924	8.107338817	145.9118942	401.5928807
Conclusion								
Increasing **density** with same rate lead to	Decrease (SOW, PUW, ROT & DRILL) with the same rate							
	Decrease Torque (ROT & DRILL) with the same rate							
	Decrease Drag with slight rate							

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Friction Factor

Table 8 – Friction Factor Effect Well #1

Well-1									
Condition	F.F		SOW	PUW	ROT	DRILL	Drag	ROT	DRILL
	C.H	O.H	[Kip]	[Kip]	[Kip]	[Kip]	[Kip]	[daN*m]	[daN*m]
Recommend	0.2	0.3	131.2327079	140.4199184	135.6994595	105.6860774	9.187210497	165.3868932	420.1097293
Variable	0.4	0.6	127.0045269	145.410218	135.6994595	105.6726981	18.40569111	330.7737863	514.7982518
	0.6	0.9	123.0007141	150.6875547	135.6994595	105.6593221	27.68684061	496.1606795	609.4623646
	0.8	1.2	119.2079433	156.2702589	135.6994595	105.6459494	37.06231563	661.5475727	704.1020754

Conclusion	
Increasing **F.F** with same rate lead to	Decrease (SOW) with the same rate
	Increase (PUW) with the same rate
	ROT WT & DRILL WT Remain Constant
	Drag increase with same rate
	Increase Torque (ROT & DRILL) with same rate

RPM & WOB

Table 9 – RPM & WOB Effect Well #1

Well-1									
Condition	RPM&WOB		SOW	PUW	ROT	DRILL	Drag	ROT	DRILL
	[RPM]	[Kip]	[Kip]	[Kip]	[Kip]	[Kip]	[Kip]	[daN*m]	[daN*m]
Recommend	120	30	131.2327079	140.4199184	135.6994595	105.6860774	9.187210501	165.3868932	420.1097292
Variable	130	35	131.2327079	140.4199184	135.6994595	100.6885056	9.187210501	165.3872219	409.7354189
	140	40	131.2327079	140.4199184	135.6994595	95.69041273	9.187210501	165.3874828	400.2629785
	150	45	131.2327079	140.4199184	135.6994595	90.69181458	9.187210501	165.3876933	392.1312016

Conclusion	
Increasing **RPM & WOB** with same rate lead to	(SOW, PUW & ROT) Remain Constant
	Decrease DRILL WT with the same rate
	ROT Torque Remain Constant
	Decrease DRILL Torque with the same rate
	Drag Remain Constant

No. HWDP

Table 10 – No. of HWDP Effect Well #1

Well-1								
Condition	BHA NO. HWDP	SOW [Kip]	PUW [Kip]	ROT [Kip]	DRILL [Kip]	Drag [Kip]	ROT [daN*m]	DRILL [daN*m]
Recommend	18	131.2327079	140.4199184	135.6994595	105.6860774	9.187210497	165.3868932	420.1097293
Variable	22	133.0054045	142.3315381	137.5402612	107.5264117	9.32613357	166.5810138	422.2064445
	26	134.8072361	144.2961166	139.421749	109.4073527	9.488880486	167.9433859	424.431933
	30	136.6333775	146.2931049	141.331545	111.3165765	9.65972743	169.4152918	426.6829788

Conclusion	
Increasing **NO. HWDP** with same rate lead to	Increase (SOW, PUW, ROT & DRILL) with the same rate
	Increase Torque (ROT & DRILL) with the same rate
	Drag Remain Constant

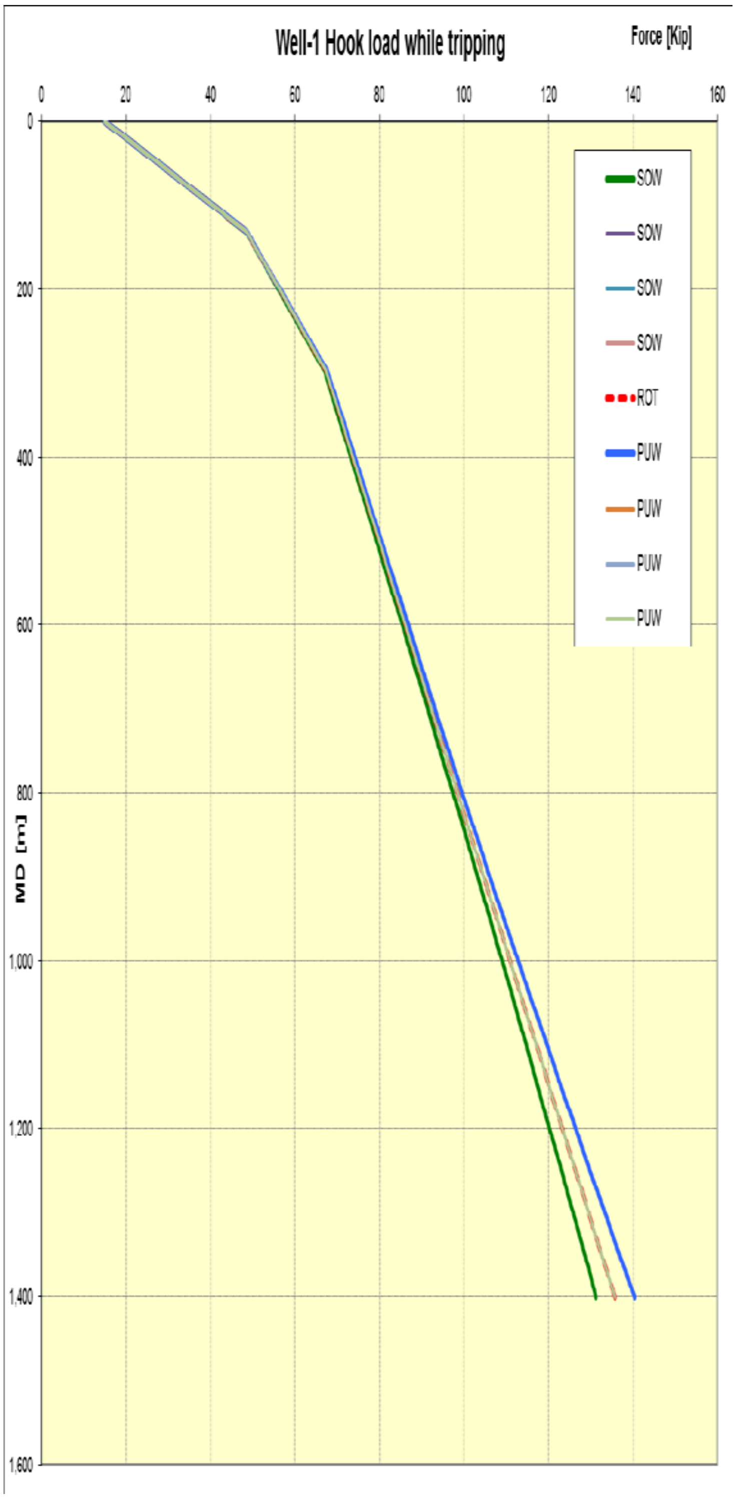
NO. DC

Table 11 – No. of DC Effect Well #1

Well-1										
Condition	D.C A.J	D.C B.J	SOW [Kip]	PUW [Kip]	ROT [Kip]	DRILL [Kip]	Drag [Kip]	ROT [daN*m]	DRILL [daN*m]	
Recommend	2	10	131.2081854	140.3608228	135.658252	105.6449406	9.152637338	165.3868932	420.1097293	
Variable	4	12	138.2644354	148.2094334	143.1003273	113.0845669	9.944997934	177.6065021	434.3713446	
	6	14	144.9806952	155.6536108	150.1713102	120.1535098	10.67291559	190.4698962	447.0515349	Over flow
	8	16	151.717434	163.0756598	157.2424543	127.222749	11.35822573	202.3864425	458.7143879	

Conclusion	
Increasing **NO. DC** with same rate lead to	Increase (SOW, PUW, ROT & DRILL) with the same rate
	Increase Torque (ROT & DRILL) with same
	ROT WT & DRILL WT Remain Constant
	Drag increase with same rate

Hook Load While Tripping & RT Torque While Tripping



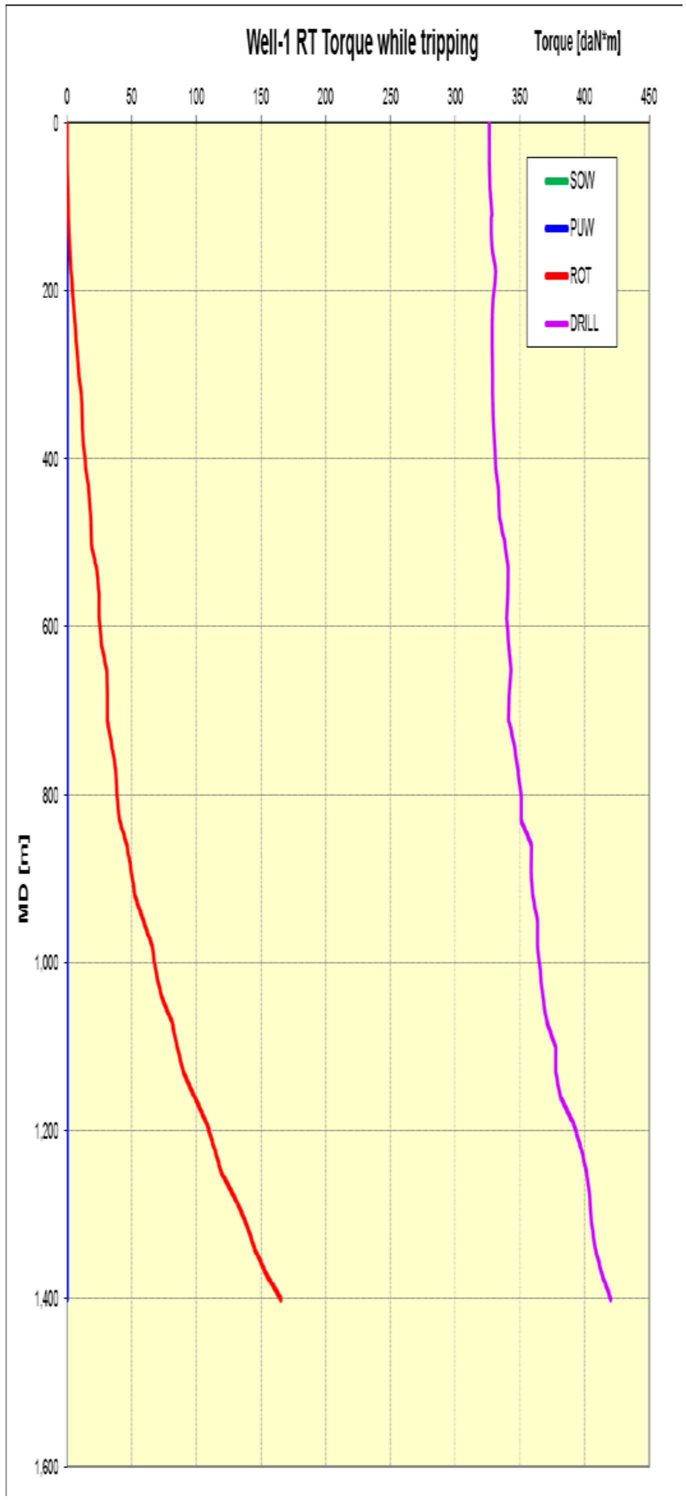


Figure 11 – Hook Load while Tripping Well #1

Figure 12 - Torque While Tripping Well #1

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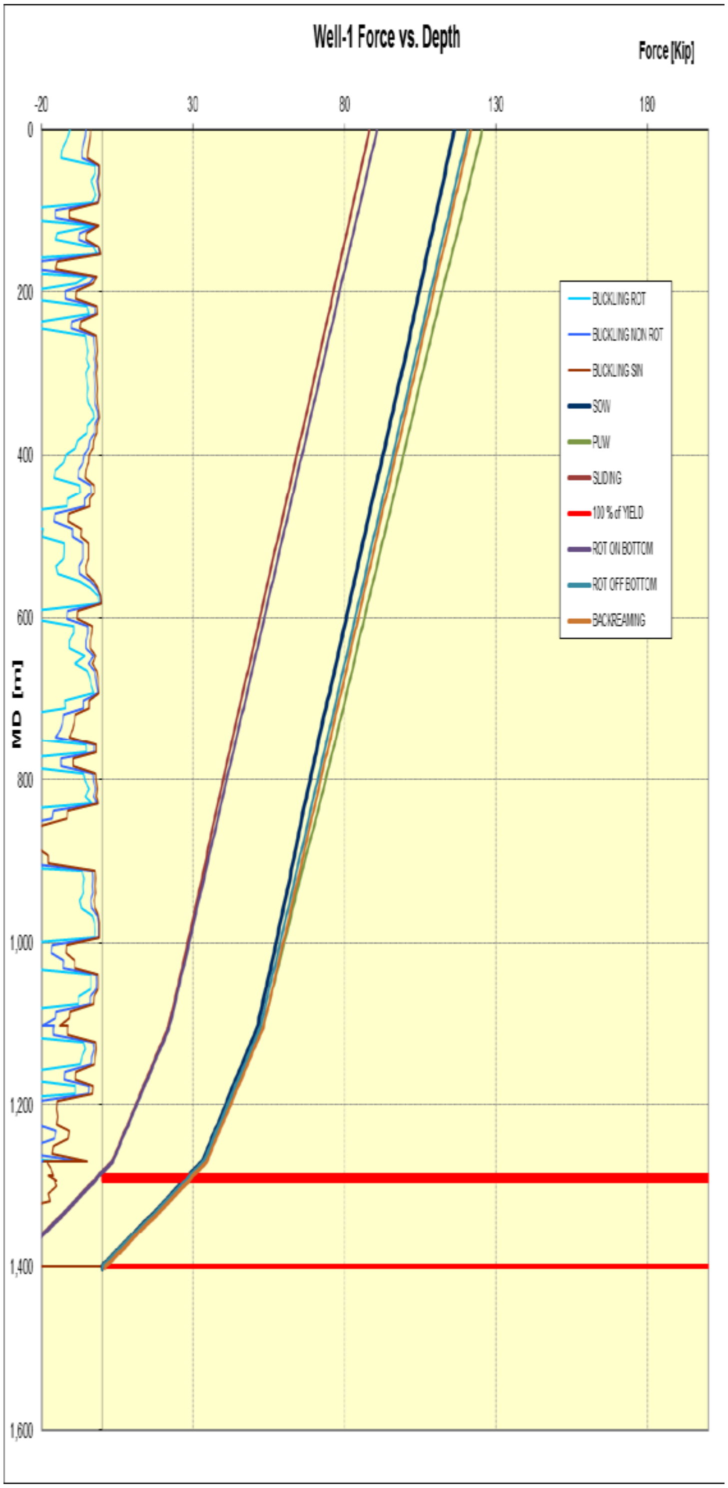
Forces & Torque Vs. Depth



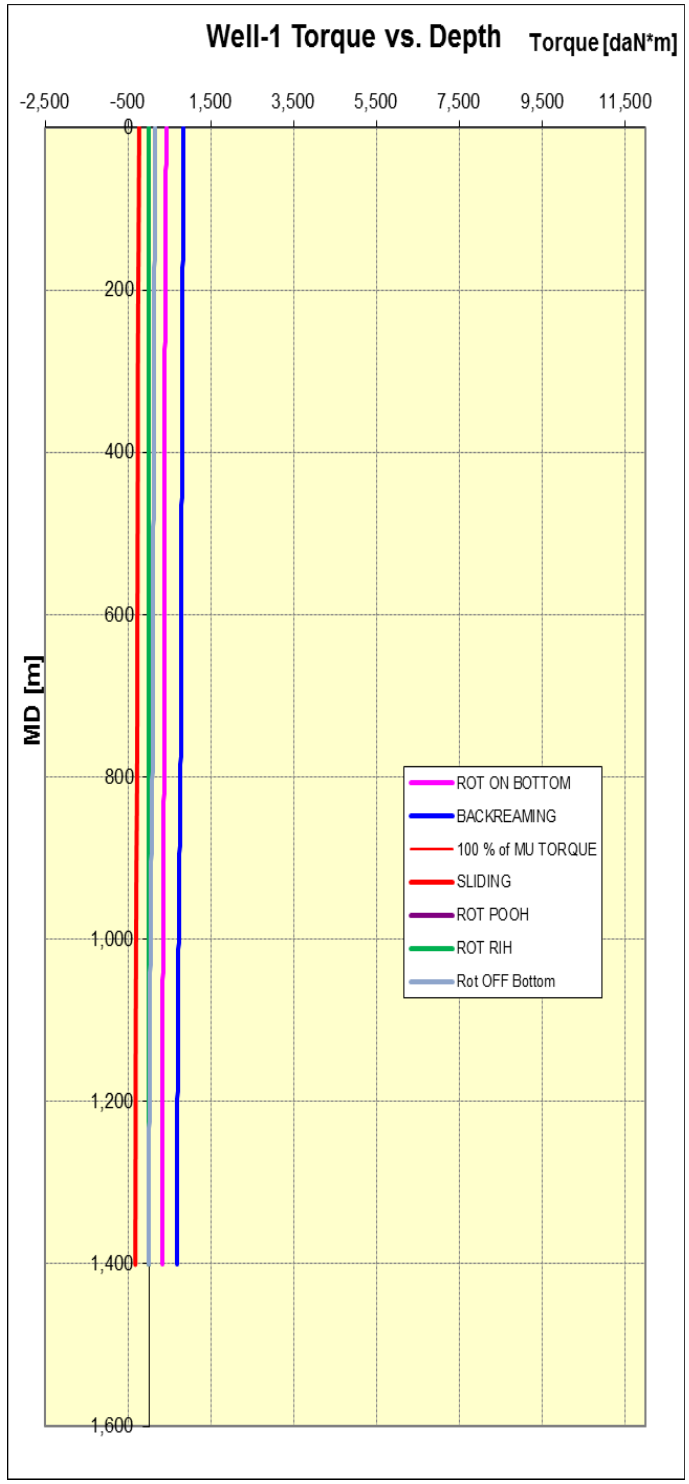


Figure 13 – Forces Vs. Depth Well #1

Figure 14- Torque Vs. Depth Well #1

Pressure Vs. Depth

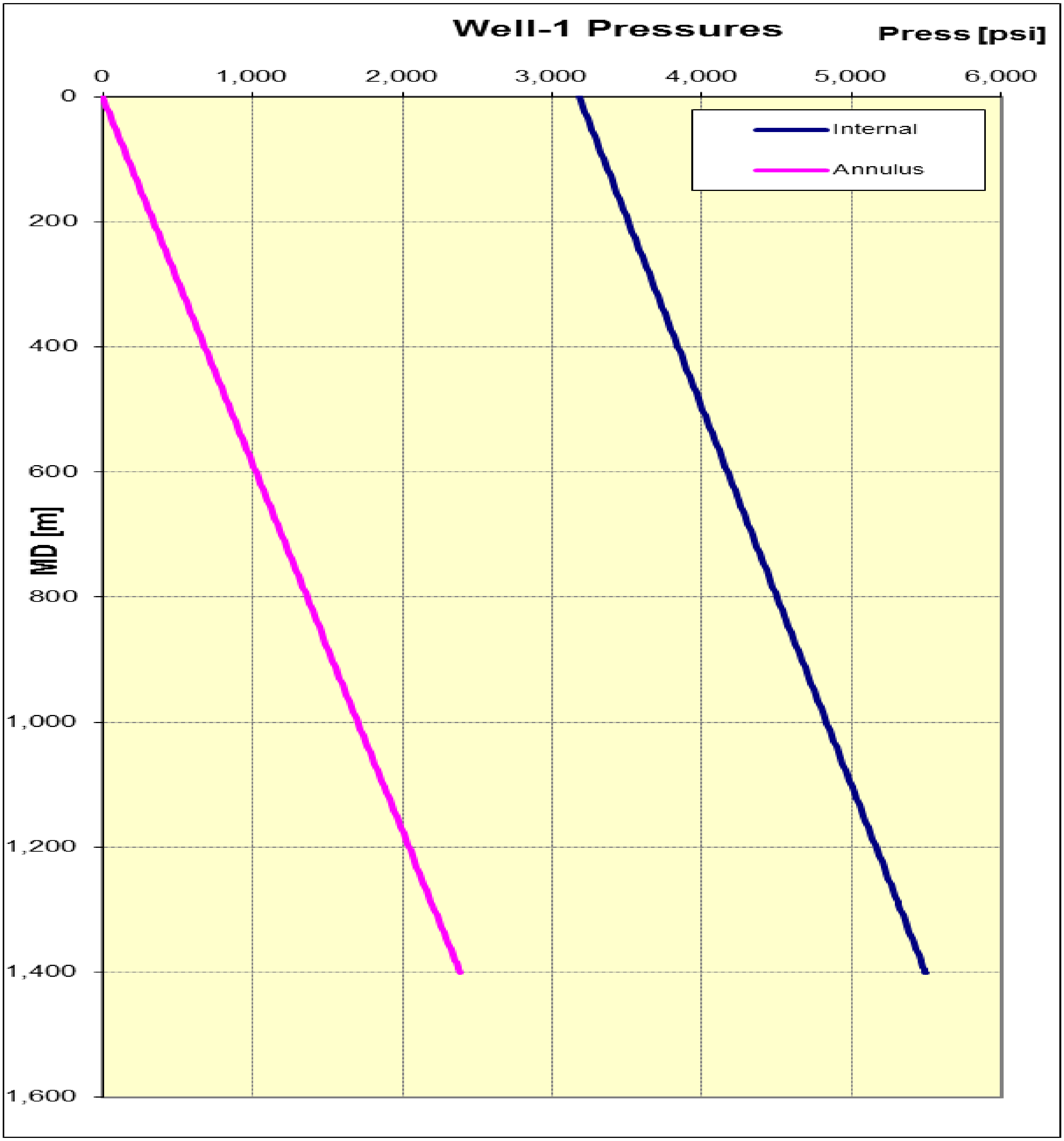


Figure 15 – Pressure vs. Depth Well #1

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Pick Up Stress, Normal Contact Force & Force Distribution While Pick UP

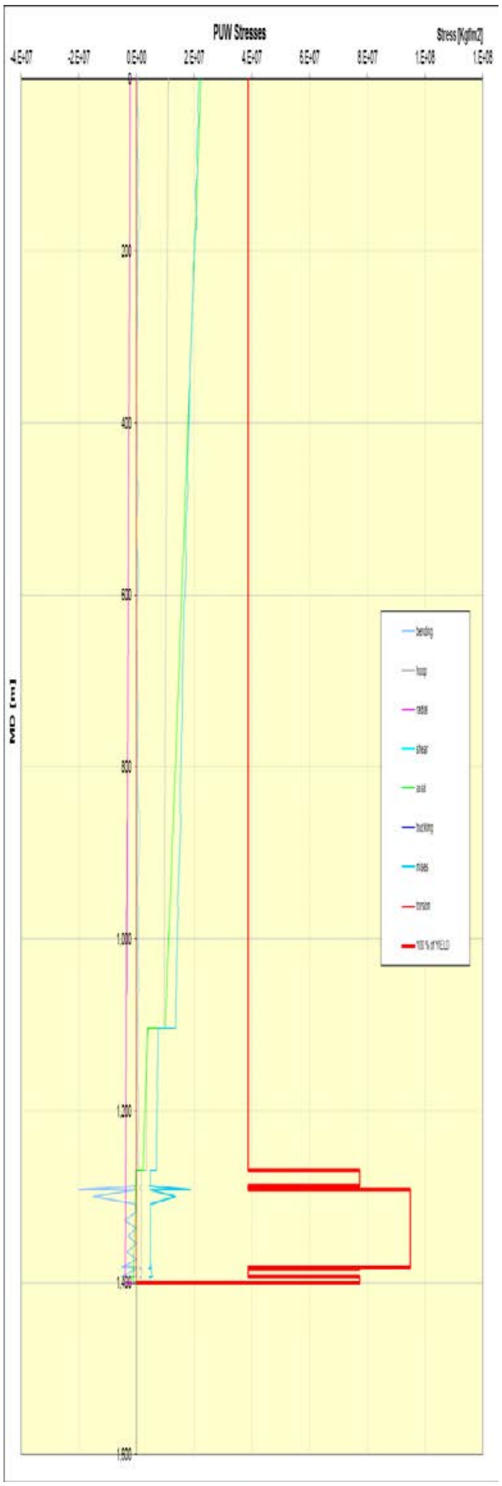

Figure 16– PUW Stresses Well#1

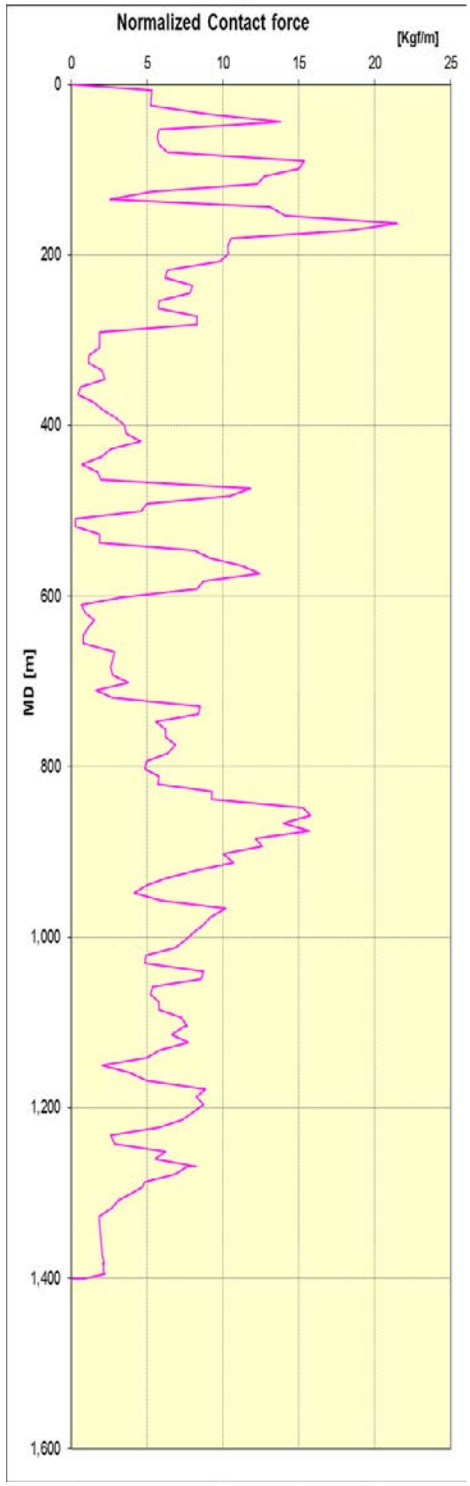

Figure 17- Normalized contact force Well#1

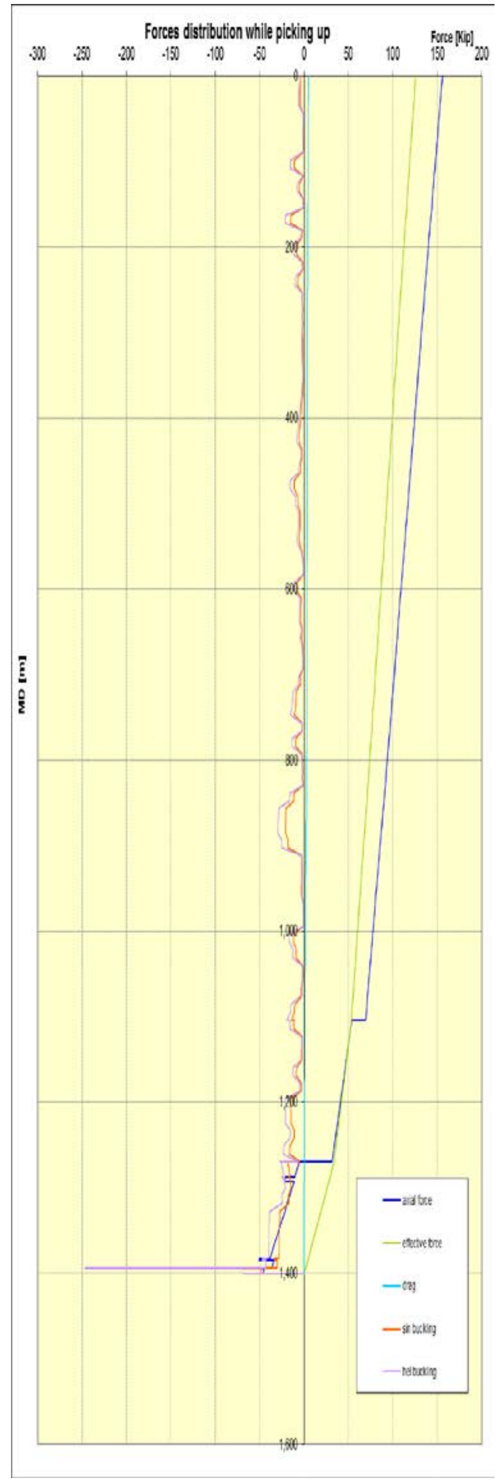

Figure 18- Force distribution while picking up well#1

Slack Off Stress, Normal Contact Force & Force Distribution Slack Off

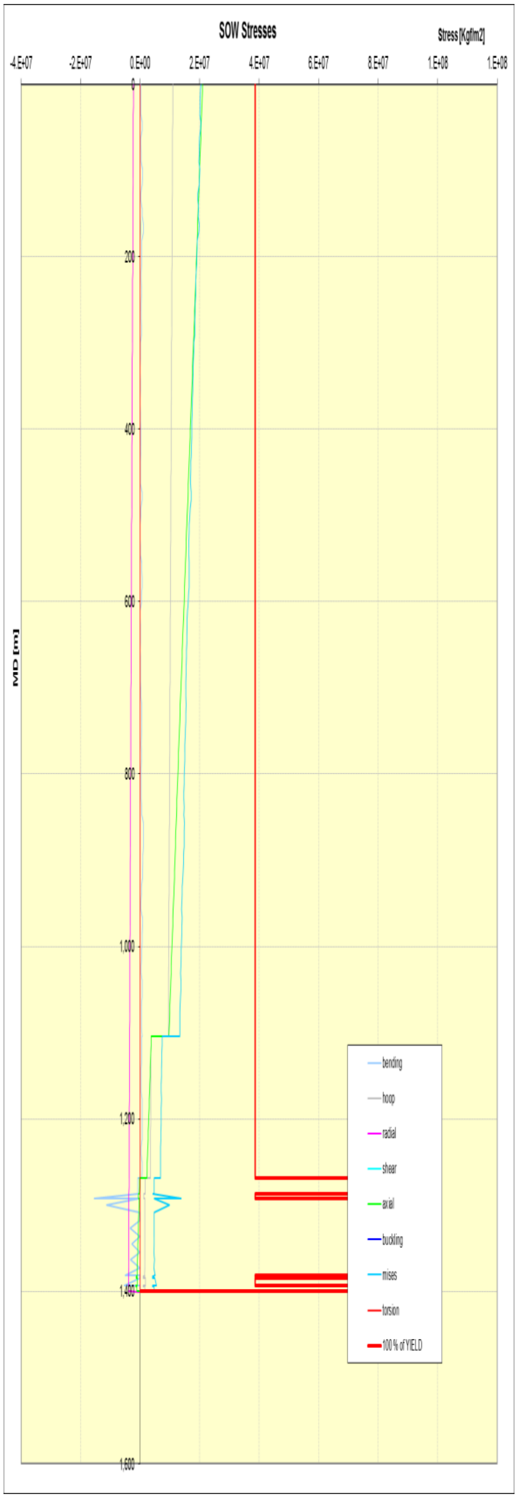

Figure 19– SOW Stresses Well#1

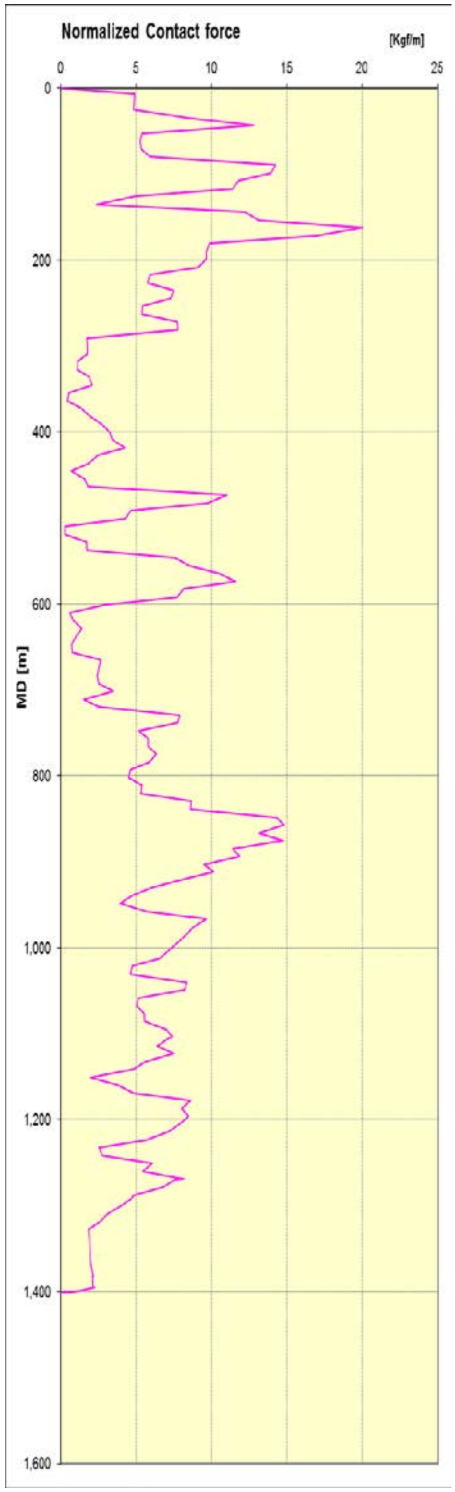

Figure 20- Normalized contact force Well#1

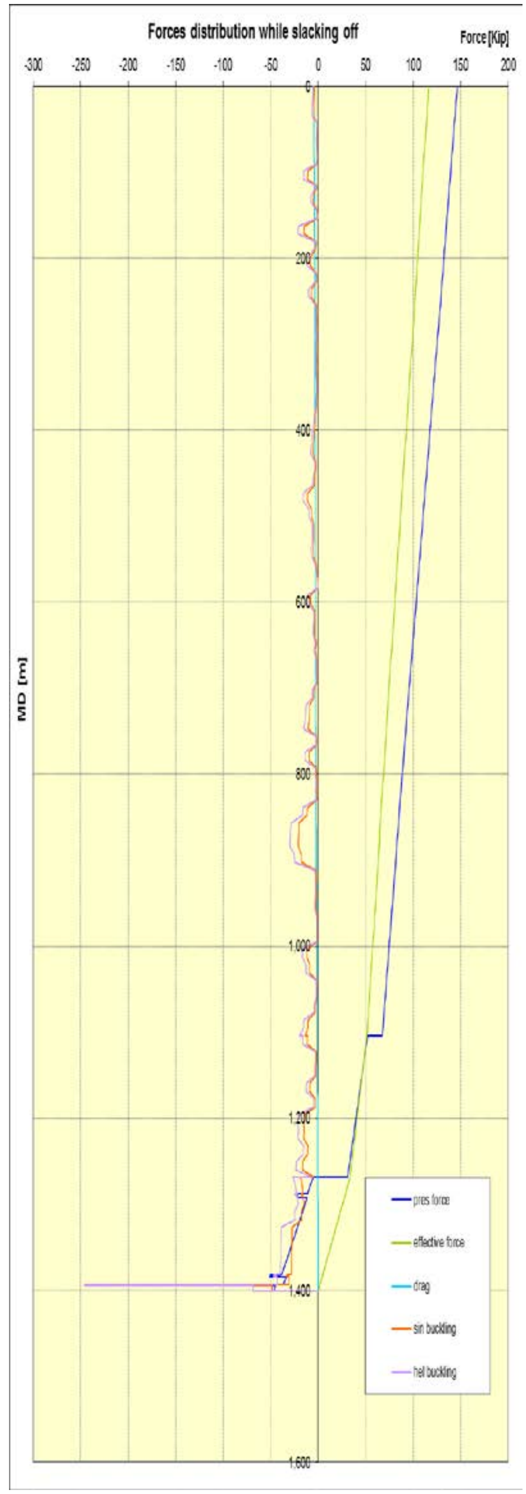

Figure 21- Force distribution while slacking off Well#1

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Sliding Stress, Normal Contact Force & Force Distribution While Sliding

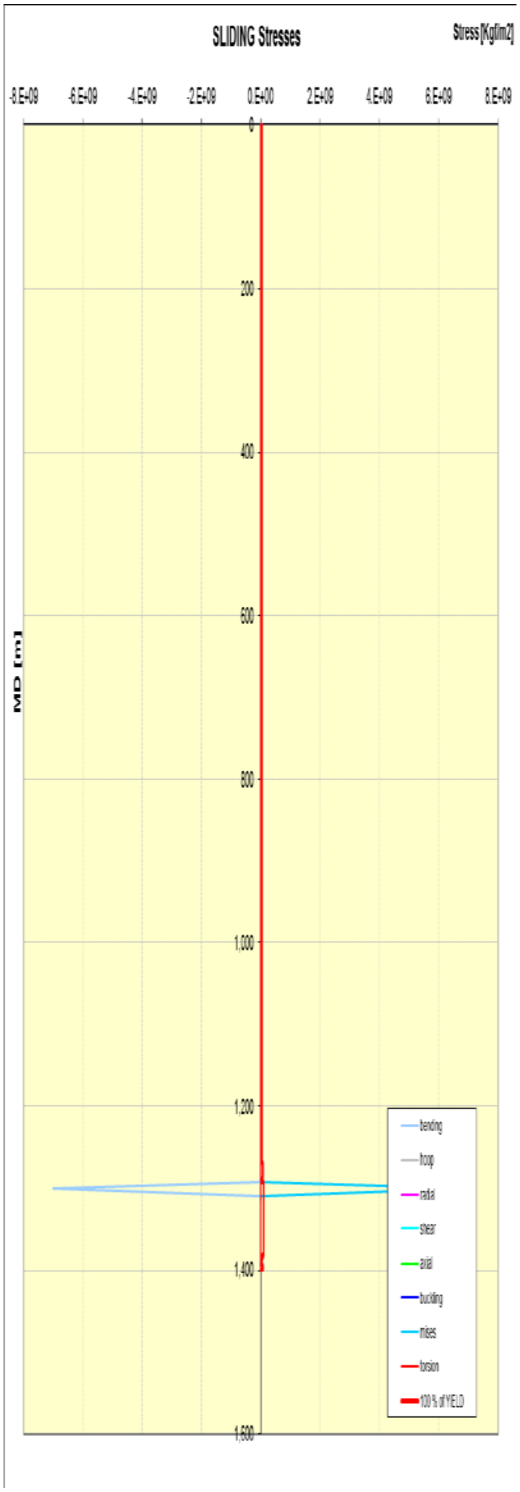

Figure 22– Sliding Stresses Well #1

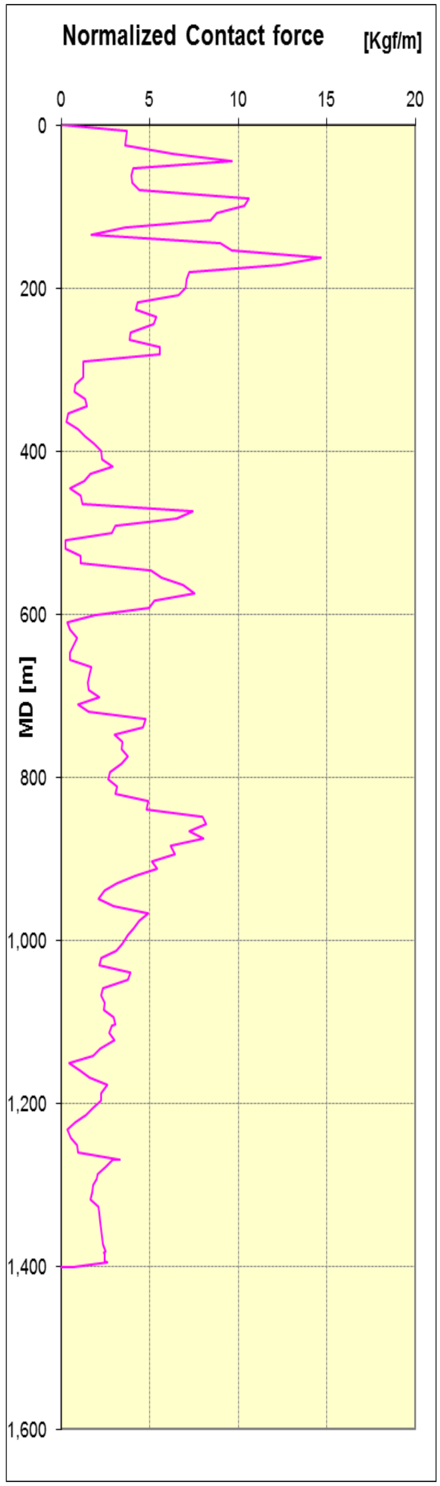

Figure 23- Normalized contact force Well#1

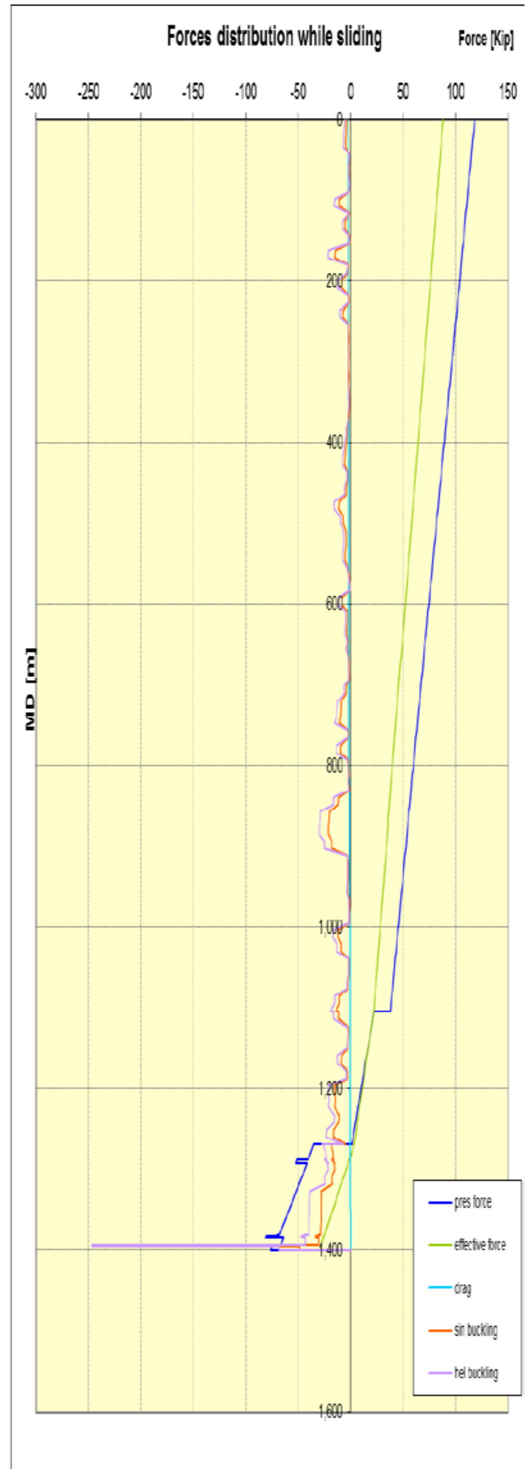

Figure 24- Force distribution while sliding Well#1

Rotation Off Bottom Stress, Normal Contact Force & Force Distribution While Rotation Off Bottom

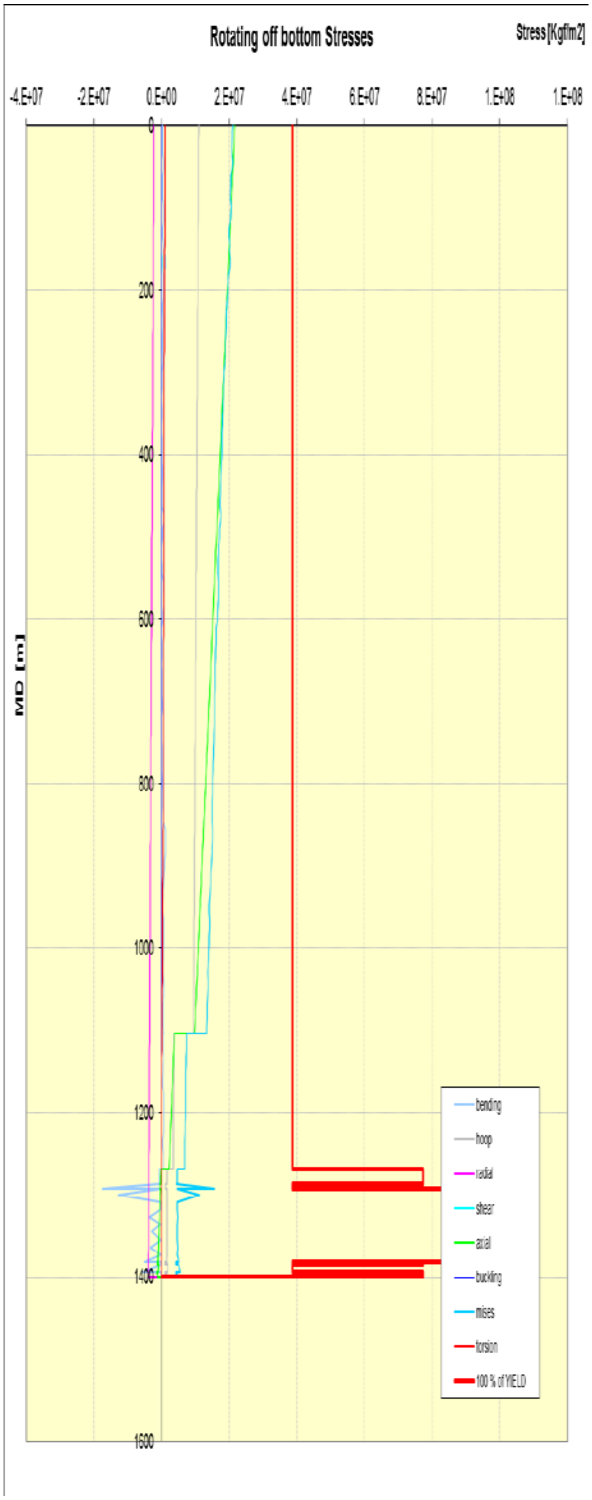

Figure 25– Rotation off BTM Stresses Well#1

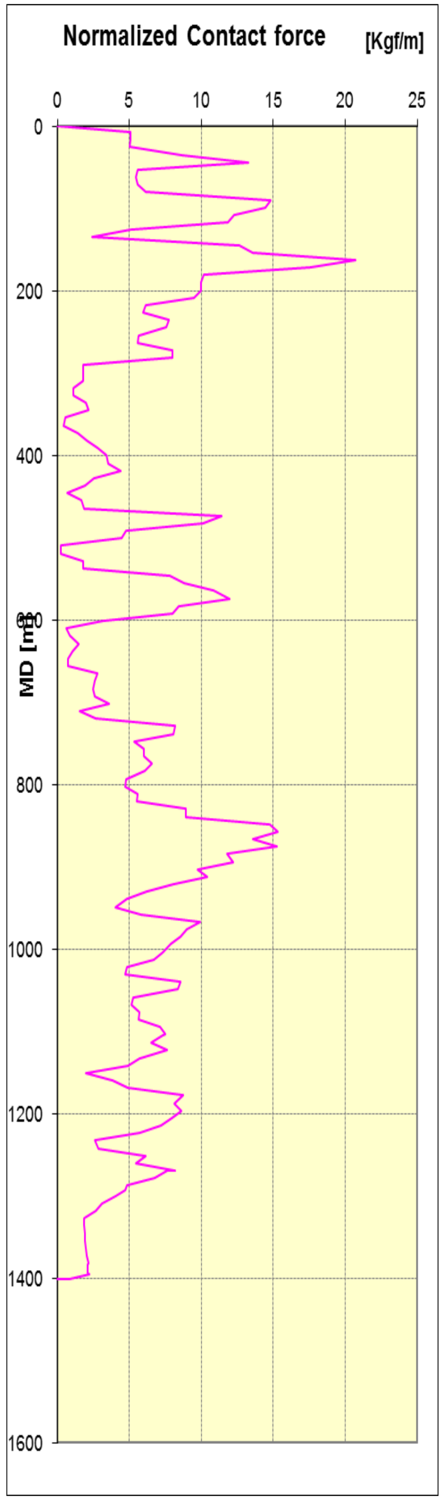

Figure 26 - Normalized contact force well#1

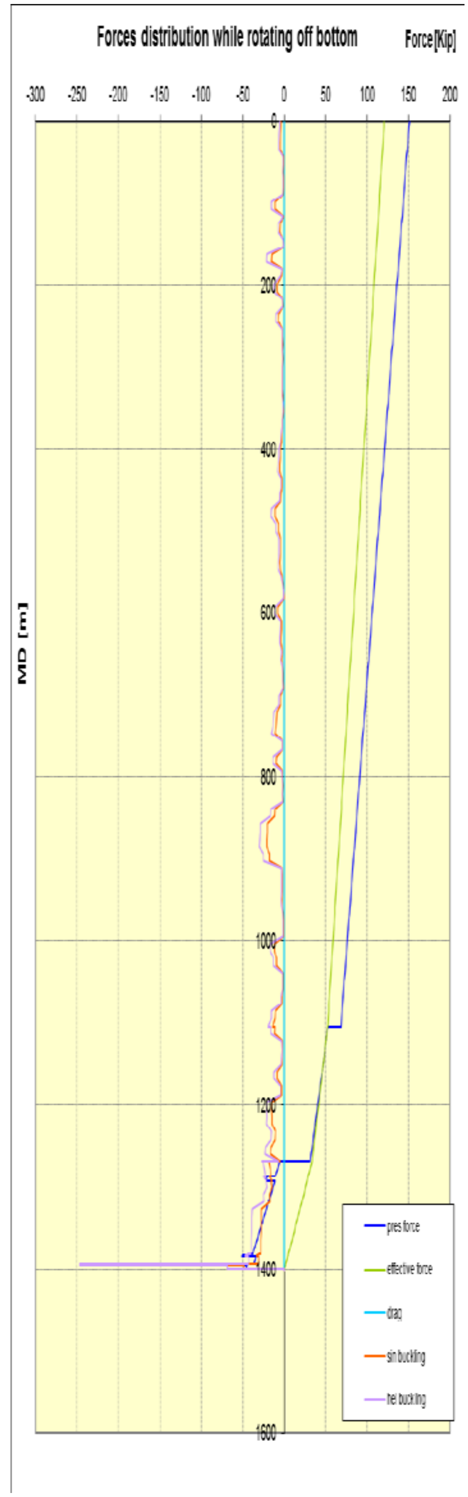

Figure 27- Force distribution while Rotating off BTM Well#1

Rotation On Bottom Stress, Normal Contact Force & Force Distribution While Rotation On Bottom

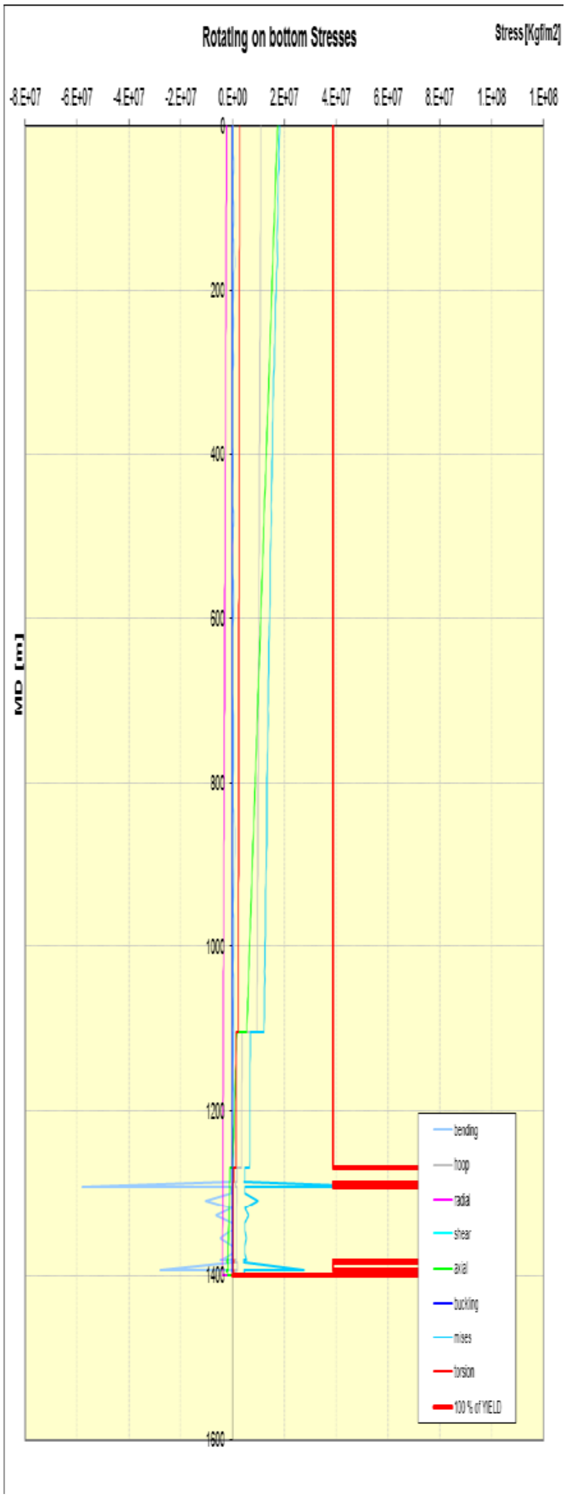

Figure 28– Rotation on BTM Stresses Well#1

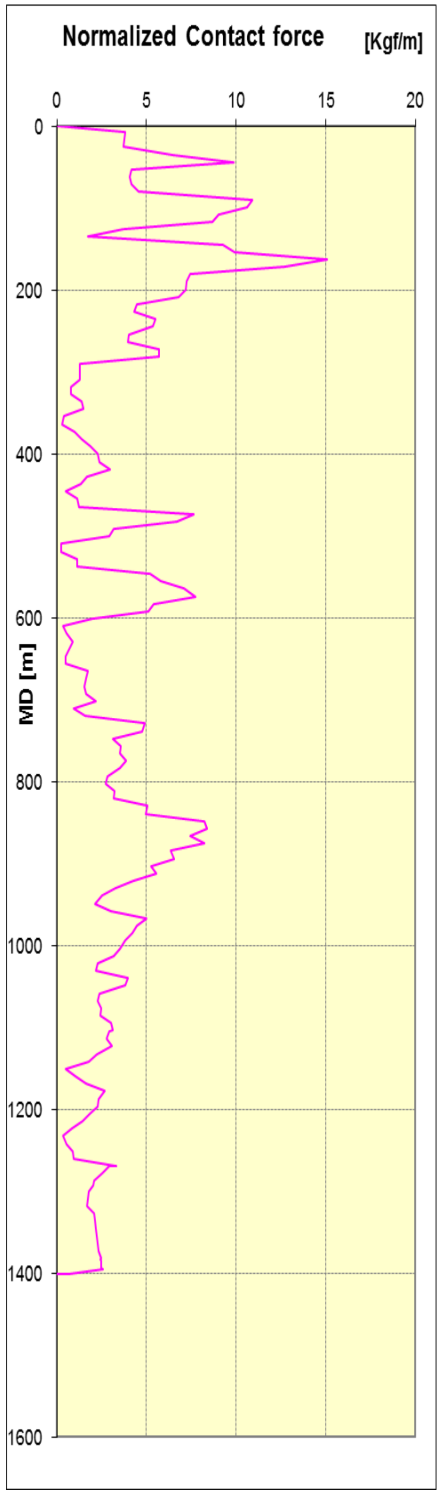

Figure 29- Normalized contact force Well#1

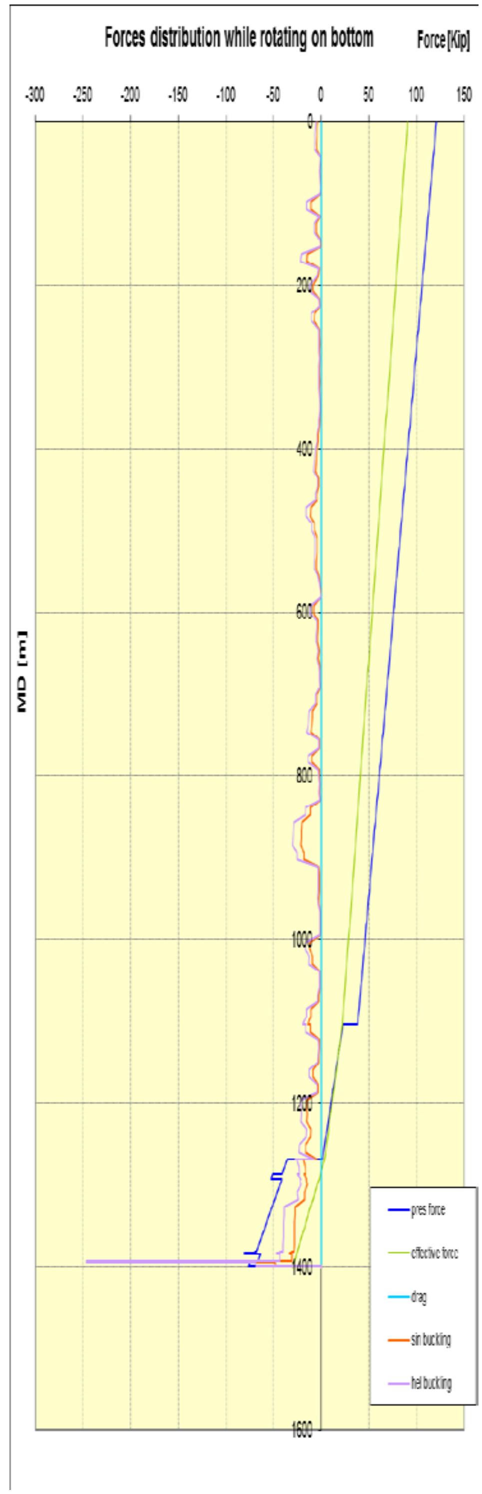

Figure 30 - Force distribution while Rotating on BTM Well#1

Summary

Table 12 - Summary stress analysis result for recommended parameter Well#1

LOAD	TORQUE AT		FORCE	STRETCH	WINDUP	NEUTRAL POINT FROM		ZERO STRESS FROM	
	SURF	BIT	AT SURF			SURFACE	BIT	SURFACE	BIT
	[daN*m]	[daN*m]	[Kip]	[m]	[rev]	[m]	[m]	[m]	[m]
TRIPPING OUT	0.00	0.00	140.42	0.52	0.00	1,400.22	0.34	1,269.16	131.40
TRIPPING IN	0.00	0.00	131.23	0.49	0.00	1,400.22	0.34	1,269.16	131.40
SLIDING	-232.88	-325.40	103.14	0.32	-0.62	1,282.42	118.14	1,269.16	131.40
ROTATING ON BOTTOM	420.11	325.40	105.69	0.33	0.83	1,283.07	117.49	1,269.16	131.40
ROTATING OFF BOTTOM	163.67	0.00	135.70	0.51	0.21	1,400.22	0.34	1,269.16	131.40
BACK REAMING	843.91	677.91	136.70	0.51	1.72			1,400.31	0.25

Max overpull (without torque) if bit stuck on bottom (at 100% of YS) 144 [Kip]

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First Author Drilling Engineer & Rig Supervisor @ South Valley Egyptian Petroleum holding Company (GANOPE), B.SC. In Petroleum Engineer, 2015, Al-Azhar University, Cairo, Egypt

Second Author Associate Professor of petroleum Engineer, Al-Azhar University, Cairo, Egypt.