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TORQUE AND DRAG ANALYSIS IN ERD WELLS

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ABSTRACT

Highly deviated wells may be described as those well whose inclination exceeds 60° for most of their length. Extended reach wells are those having MD/TVD ratio ≥ 2. It is possible to extend directional drilling techniques to increase the inclination to 60° to 90° although certain alterations may have to be made to drilling practices. Certain modifications to standard rig equipment may also be necessary to successfully drill these high angled wells. ERD wells drilled in specific fields and with specific rigs, equipment, personnel, project teams, etc. do not necessarily imply what may be readily achieved in other areas. Because of the myriad of variables which control drilling mechanics and performance, local ERD definitions should be developed in terms of the extent of experience within specific fields and with specific rigs. As one example aspect, the feasibility of ERD wells is inherently tied to the ability to manage wellbore stability. This topic alone is impacted by local geology, in-situ formation stresses, possible tectonic influences, shale reactivity, proposed well inclinations and azimuthal orientations, etc. The primary means of managing wellbore stability via mud weight, mud chemistry, casing points, etc. are likewise impacted by considerations such as loss circulation zones, permeable zones which may cause differential sticking, environmental constraints affecting mud selection

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and cuttings disposal, and regulatory requirements and production objectives which constrain hole/casing programs.

ERD APPLICATIONS

- *ERD has primarily been used to access reserves from existing offshore platforms*
- *The development of offshore reserves from onshore facilities.*
- *Better optimization of development schemes through the minimization of offshore facilities and the optimization of their location*
- *To have a link between ERD and horizontal drilling. Horizontal wells are now commonplace and can offer advantages in terms of enhanced rates, increased reserve access, increased fracture exposure, lower sand face drawdown, reduced water/gas coning, etc.*

In a directional well, the friction between the drillstring and the walls of the well produces drag and torque. Drag is produced when the drillstring is moving and torque is produced when the drillstring is rotating. Knowledge of torque and drag will enable the selection of an optimum well profile and optimum size and weight of the drillstring and its components. In horizontal wells, it is usual to run the heavy-walled Drillpipe (HWDP) along the curved section of the wellbore to counteract the forces caused by bending and drag.

The following predictions must be made when designing a horizontal well:

- *Torque and drag while drilling with surface rotation*
- *Torque and drag while steering a downhole motor*
- *Drag forces while tripping*
- *Buckling forces on the drillstring*

The magnitude of the torque and drag is determined by the magnitude with which the pipe contacts the hole wall and the friction coefficient between the wall and pipe. Unfortunately, friction is always present and will contribute to the force required to move the object. The friction force is equal to the normal force times the friction coefficient.

Keywords: ERD Wells, Torque and Drag, Horizontal Wells, Friction, HWDP

INTRODUCTION

One of the most significant problems in extended reach well is torque and drag which is caused by the friction between the drill string and the wall of the drill hole. It is the critical parameter in ERD operations for properly sizing the rotary and hoisting equipment of the rig, selecting optimum well profile and also in the prediction of drill string design.

The magnitude of torque and drag is determined by the magnitude with which the pipe contacts the hole wall and the friction factor between the pipe and the wall. Friction factor governs the nature and amount of friction forces acting opposite to the pipe surface. Its values are independent of the well inclination and depend on hole tortuosity and lubricity of drilling mud. Torque and drag posed limitations and complexity in drilling extended reach wells due to their long lateral profile which converts the drill string tension weight into the side weight hence increase the contact surface of pipe with hole walls. Buckling is also one of the major concern in extended reach wells as its occurrence increase the torque and drag to very high level. It occurs when the compressive force in the string becomes greater than the gravity weight of the drill string. Some additional measures used at present times by the drilling companies to reduce the friction factor are lubricant addition, changing mud lubricity and use of spiral drill collars & heavy weight drill pipes.

A proper modelling helps to select the best of the available trajectory profile, best of the available drill string design for the selected trajectory and drill the well within the desired economic limits.

OBJECTIVES:

1. To monitor the effects of T&D in the extended reach wells.
2. Identify the problems that affect the magnitude of torque and drag like buckling, lock up, dog legs and high friction co efficient.
3. The limitations posed to keep T&D within limits of rig equipments. Some of these are maximum available WOB, maximum available drilling torque, maximum allowable hook load and maximum tensile yield strength of the drill string components.

4. Some solutions that can be used in reducing T&D, reducing friction co efficient and maintaining well bore quality.
5. Buckling behavior of drill string is monitored at various depths resulting high T&D.
6. To quantify the equations involved in T&D and used those to solve for the available case of an extended reach horizontal well.
7. To select the BHA that maintains the hole quality and minimize well bore tortuosity.

CASE STUDY ANALYSIS

Our case includes the Maersk Oil Qatar (MOQ)'s world record BD-04A well drilled in may 2008 in offshore Qatar. This was the successful result of engineering efforts to increase extended reach capabilities. MOQ started to develop the Al shaheen field offshore Qatar in 1994 with the application of horizontal drilling techniques in the North Sea. At that time 10,220 feet was the longest horizontal length drilled by MOQ. In May 2008 the BD-04A well was completed with a record horizontal length of 35,439 feet. This well set a new world records for both the longest well at 40,320 feet MDRT and the longest along hole departure of 37,956 feet. The introduction of new techniques has allowed existing constraints to be successfully challenged and overcome. This was achieved through the application of sound engineering principles and continuous optimization during the field development phases.

Our case study will review challenges and planning, leading through to successful drilling of the BD-04A well. The study will outline the achievements, improved practices and the engineering analysis of the field data where key learning points have been shared for future use and applications. It will show that even when constrained by certain limitations such as rig capacity, major step changes can be achieved by optimizing basic operating parameters.

KEY CHANGES MADE TO REACH TARGET DEPTH

Torque and drag is the major challenge posed through while drilling BD-04 A well and taking all these factors of torque and drag into consideration subsequent changes were made from time to time to make reach the target depth of 40,320 ft MDRT. The major target depth deciding factor here was the maximum torque allowable by the top drive that is capable of providing 40 k ft-lb of torque @120 RPM. At this depth whole available torque is consumed and if drilling was continued ahead of the target depth the torque limit exceeds that of top drive capabilities.

Also to meet the challenges of Torque and Drag below the target depth several changes were made from time to time. These include:

- Drill Pipe upgrades to high torque connections to maximize the torque capability of the top drive.
- A tapered drill string with 4” x 5” d/p assembly is used with slim OD in lower part that significantly reduced torque and friction factor.
- Lubricants were added at certain depths to increase torque and reduce friction factor.
- Special attention was given on ECD management to maintain borehole stability and reduce induced well bore losses. This is done through hole enlargement with mud system, tapered drill string with a section of slim OD drill pipes, and thin mud rheology.
- Emphasis was also given to maintain the quality well path with in maximum permissible dogleg value to reduce the severe dogleg effects.
- The use of RSS in the continuous build top hole sections resulting in a smooth catenary well bore curve which facilitated in pushing the ERD limits.

DATA AVIALABLE

- **Well Data:**

Well Parameters:

Total Hole Length = 40,320 ft (MDRT) with 3,605 ft (TVD), Hole size = 8.5 inch, Casing shoe = 4871 ft (MDRT), Shoe size = 9.625 inch, Horizontal length = 35,439 ft, Inclination angle = 86^0(at 4,550 ft), Azimuth at 28,850 ft = 99.2deg, Azimuth at 40,320 ft = 134.2deg, Mud weight used = 9.5 ppg

- **Drill String Data:**

When the drilling is started after 23,630 ft MDRT

Length	Components	Grade of Pipe	
To surface	5” #19.5 ppf	GHT50	G105
17,750 ft	5” #19.5 ppf	GNC50	G105
6,956 ft	4” #14 ppf	GXT39	G105
482 ft	5” #19.5 ppf	GNC50	G105

9 ft	5” #50 ppf	HWDP – GP
120 ft	6.75” D/C #105.3 ppf	

- **WOB**upto 23,630 ft with 5” d/p = 15,000 lb

When the drilling depth is below 23,630 ft MDRT

Length	Components	Grade of Pipe	
To surface	5” #19.5 ppf	GHT50	G105
25,188 ft	5” #19.5 ppf	GNC50	G105
9 ft	5” #50 ppf	HWDP – GP	
120 ft	6.75” D/C #105.3 ppf		

- **OD & ID of Tool Joints:**

Component	OD(in.)	ID(in.)
D/c	6.75	2.5
HWDP	5	2.5
4” D/P	4.875	2.8125
5” D/P	6.625	3.5

- **Tensile Yield Strength of drill pipes:**

HT 50 = 9, 39,100 lb, NC 50 = 11, 09,900 lb, XT 39 = 603,000 lb

DATA INTERPRETED:

Well Trajectory data: Double build curve design

Input parameters assumed,

BUR_1 = 2.72 ^{0}/100 ft, BUR_2 = 2.42 ^{0}/100 ft, Slant angle = 36deg, Slant length = 350 ft, TVDRT of EOB_2 = 3,482 ft, Length of horizontal section = 35,439 ft, Inclination (EOB_2) = 89.8^0

Output parameter derived through double build curve analysis,

KOP_1 = 985 ft

EOB_1 (TVD)= 2223 ft Radius of build = 2107 ft MDRT = 2308 ft

Departure = 402 ft

KOP_2 (TVD)= 2506 ft MDRT = 2658 ft Departure = 608 ft

EOB_2 (TVD) = 3482 ft Radius of build = 2368 ft MDRT = 4881 ft Departure = 2515 ft

Target(TVD) = 3605 ft Departure = 37,954 ft MDRT = 40,320 ft

KOP$_1$	**EOB$_1$ (TVD)**	**KOP$_2$ (TVD)**	**EOB$_2$ (TVD)**	**Target (TVD)**	
Azimuth	0	51.2^0	51.2^0	99.2^0	134.2^0
North	0	351 ft	480 ft	953 ft	-8,387 ft
South	0	168 ft	328 ft	2,119 ft	35,578 ft

OBJECTIVE OF THE CASE STUDY

Our objective of study is:

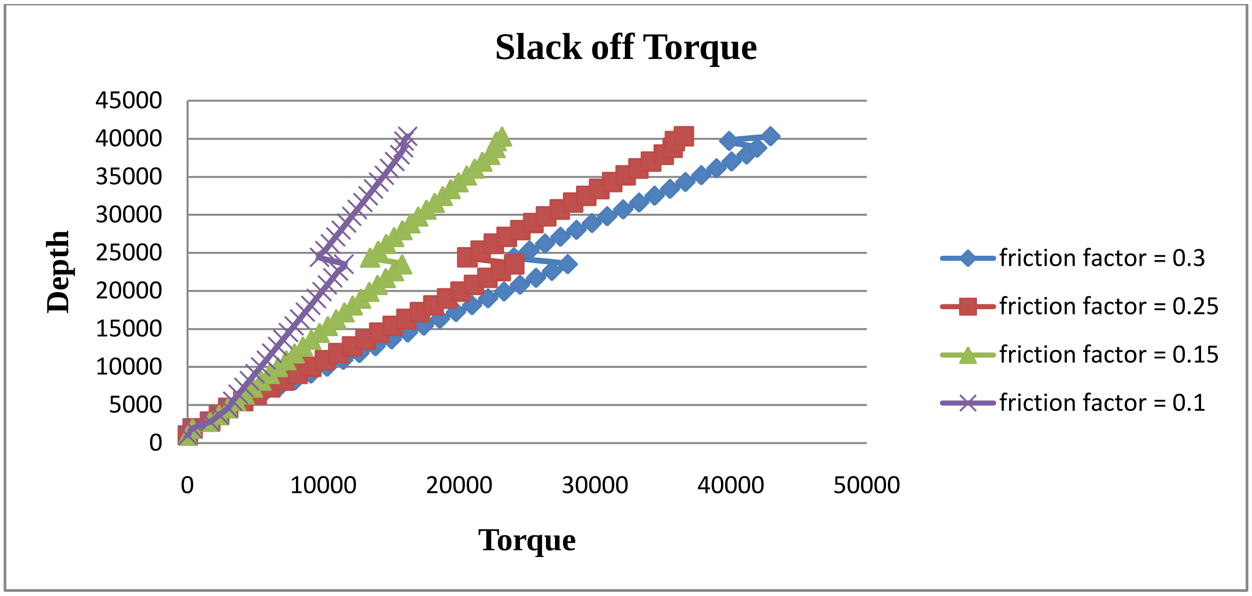
1. To identify the Torque, Drag and Buckling forces that acts on the drill string at each depth up to target depth.
2. Each force are calculated for four cases of Pick up, Slack off, Off bottom and drilling on bottom.
3. Hook load is calculated for all four at each depth.
4. Critical Buckling load analysis tells whether the string buckles or not with the required WOB.
5. The whole analysis is done for numerous values of friction factors and the variation in parameters with depth.
6. To extend the analysis for the complete well results are plotted on graph from top to bottom target depth.
7. Also the comparison is made with using 5" D/p instead of tapered drill string for each case and results are plotted.

RESULTS

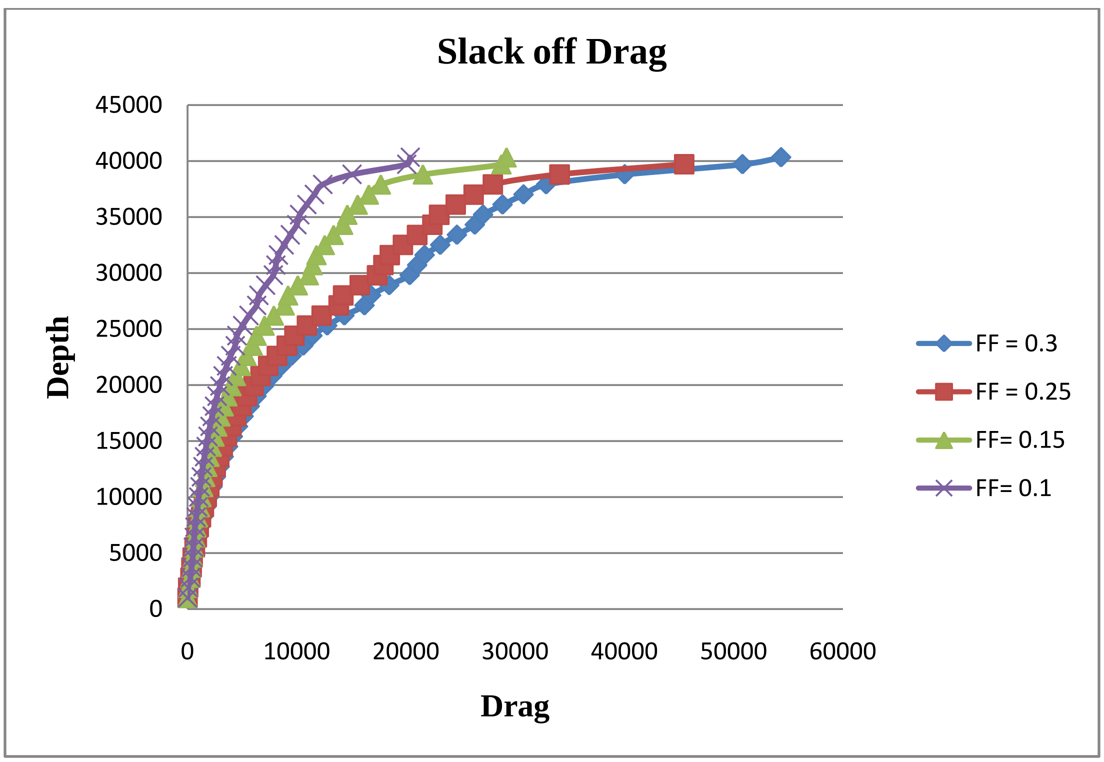
The result derived from our case study analysis is as follows:

SLACK OFF LOAD VARIATIONS WITH DEPTH

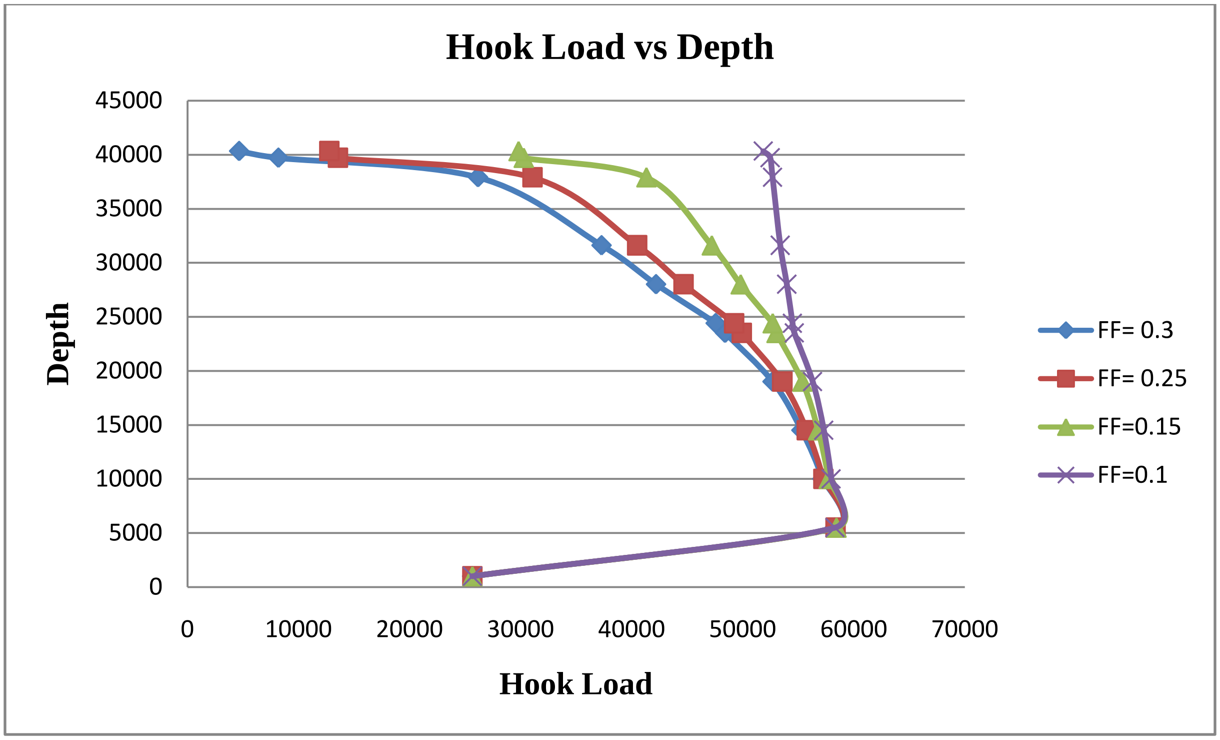
In slack off with rotation the effect of torque is high than drag values:



Slack off vs. depth

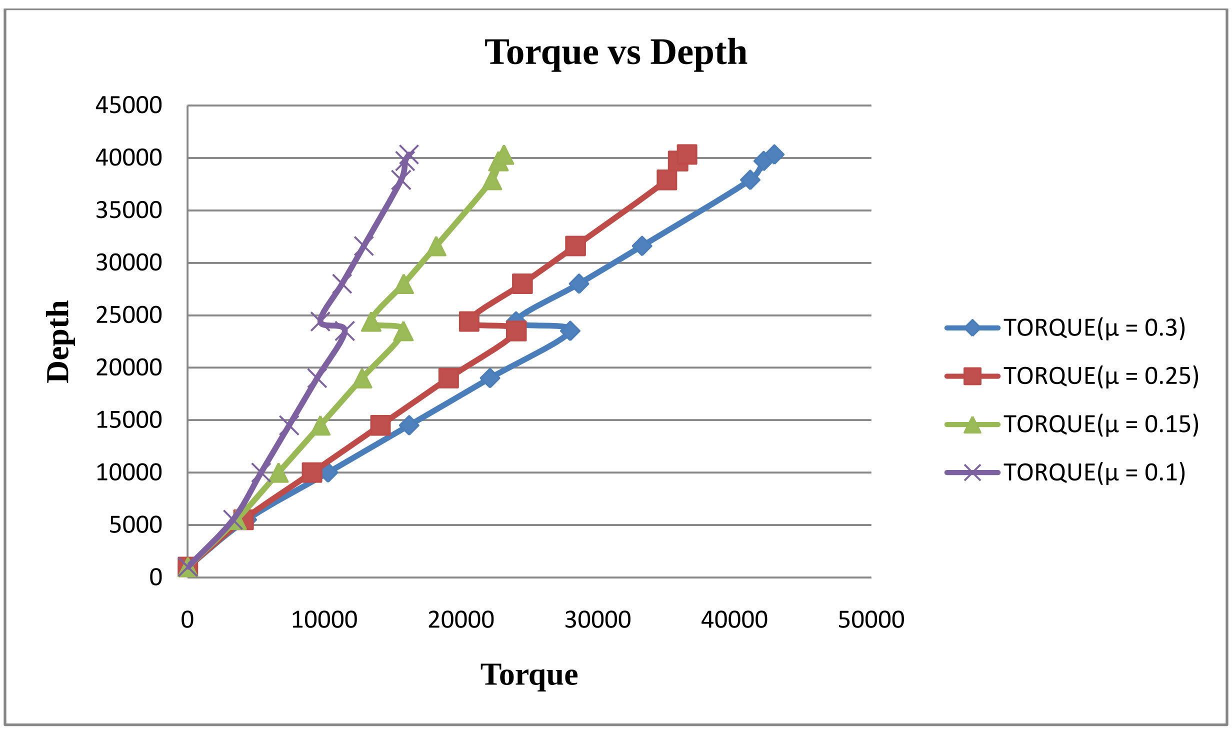


Slack off drag vs. depth

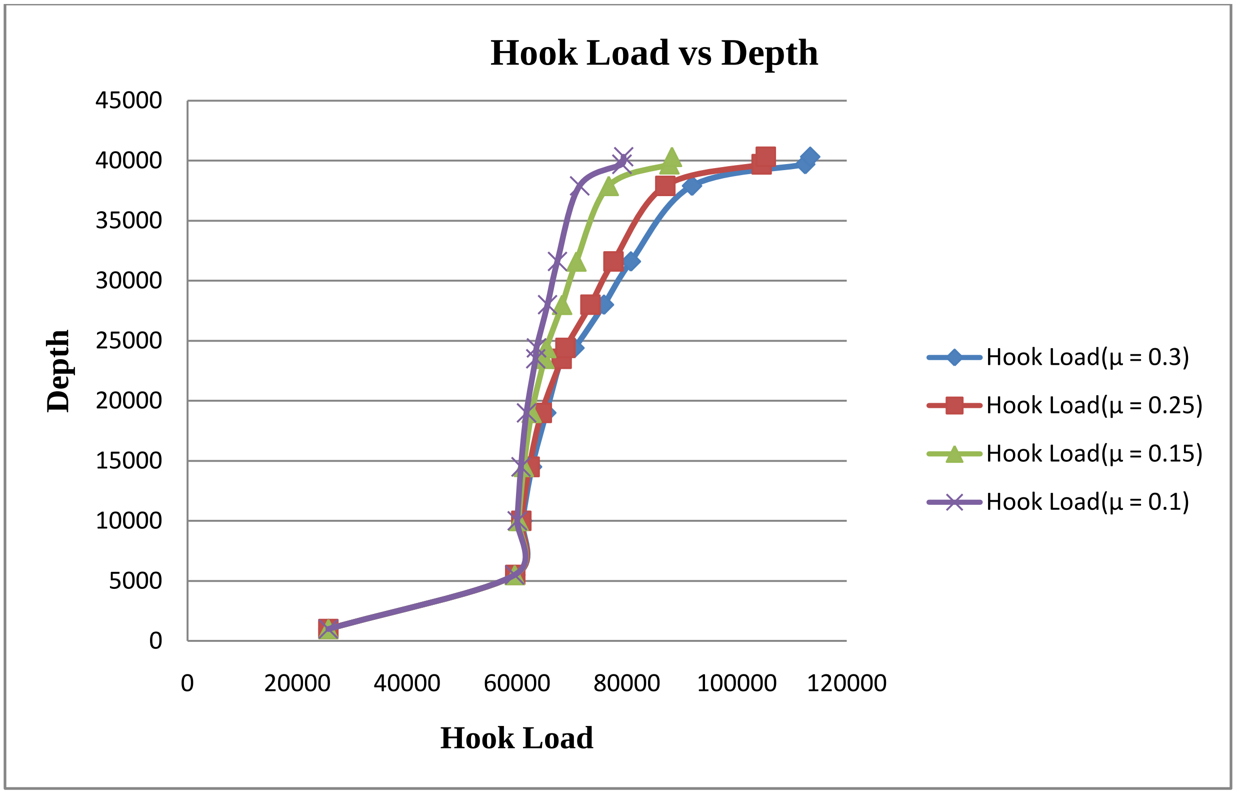


Hook load vs. depth

PICK UP LOAD VARIATIONS WITH DEPTH

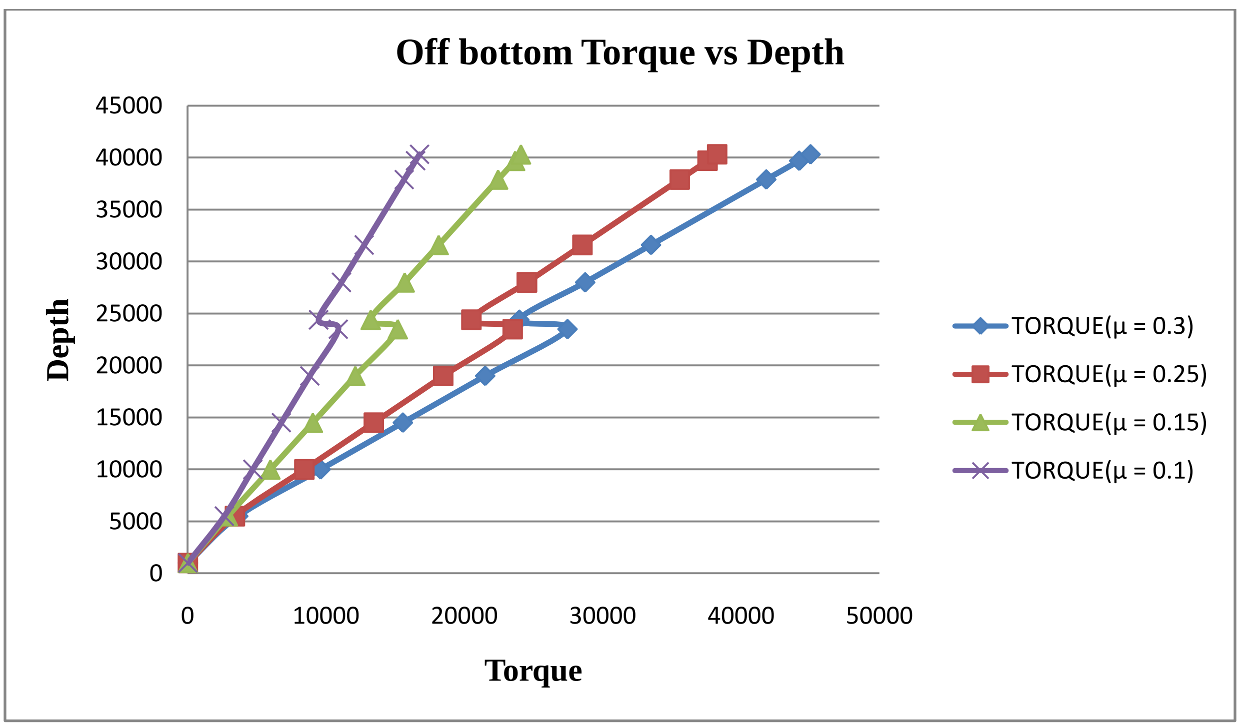


Torque vs. depth



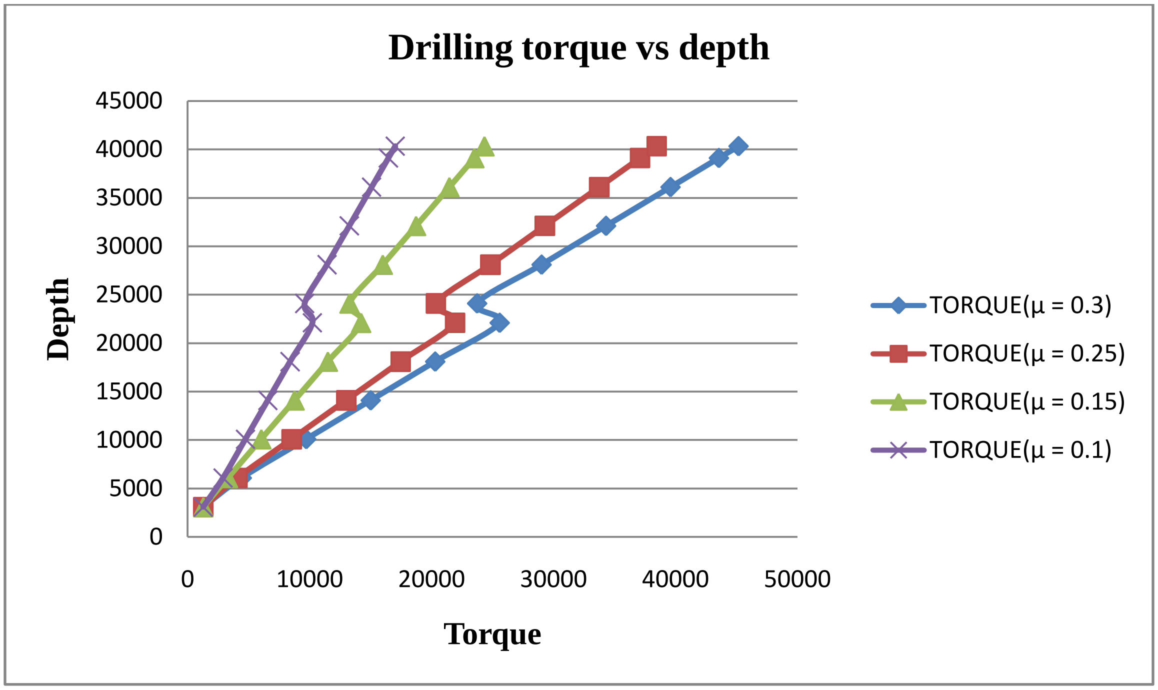
Hook load vs. depth

OFF BOTTOM LOAD VARIATIONS WITH DEPTH

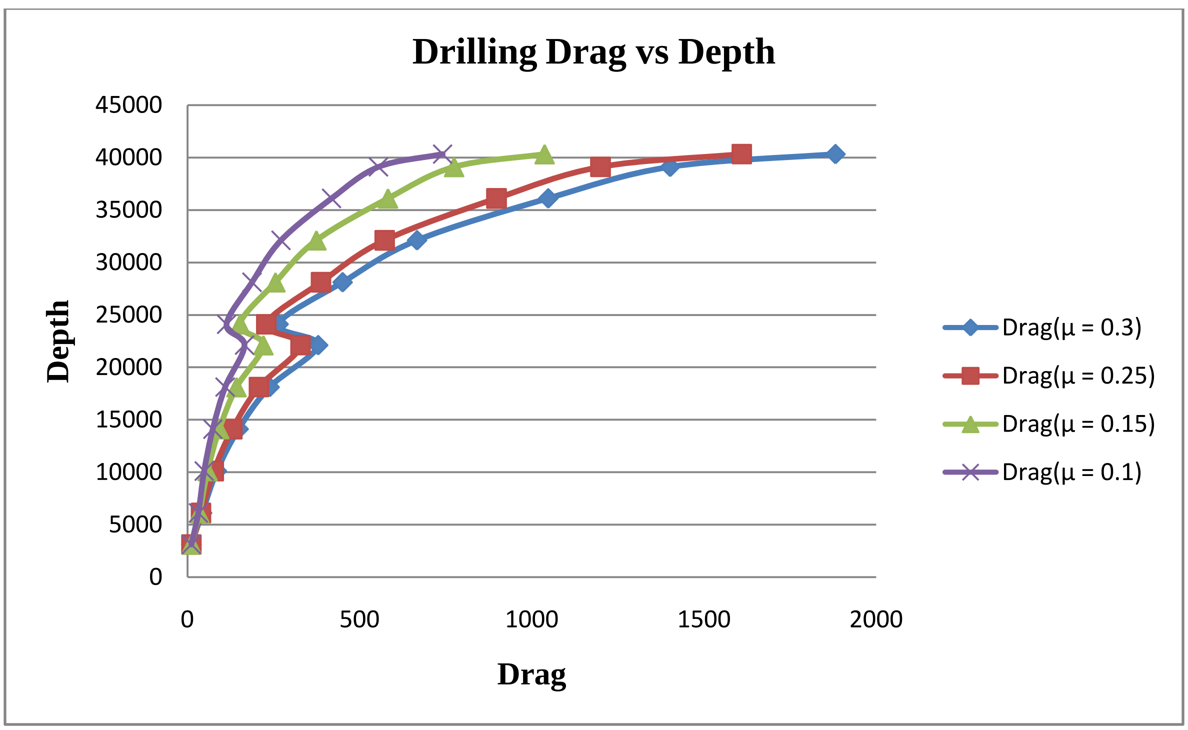


Off bottom torque vs. depth

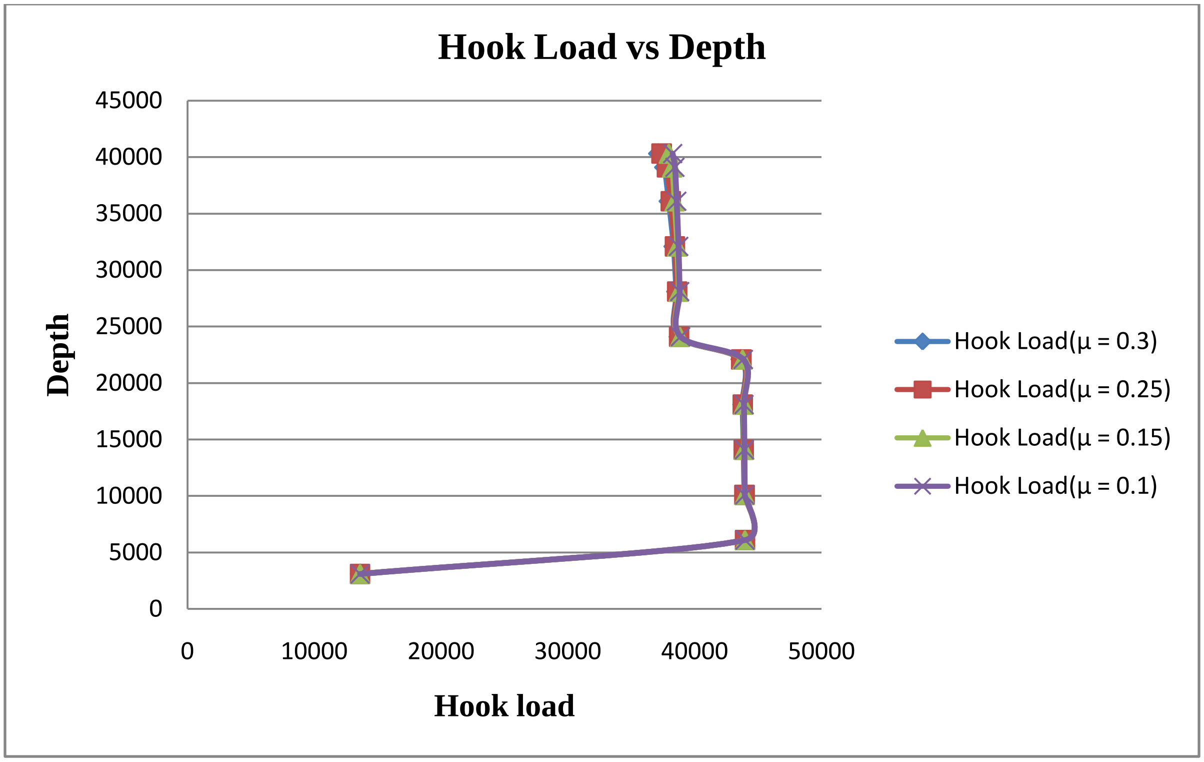
DRILLING LOAD VARIATIONS WITH DEPTH



Torque vs. depth



Drilling drag vs. depth



Hook load vs. depth

BUCKLING BEHAVIOR

Section	**Drill Pipe**	**Critical buckling load ,lb**
Horizontal	4" Drill Pipe	70,004
	5" Drill Pipe	2,58,827
Lower Build	4" Drill Pipe	57,702
	5" Drill Pipe	1,93,062
Tangent	4" Drill Pipe	35,052
	5" Drill Pipe	1,04,585
Upper Build	4" Drill Pipe	25415
	5" Drill Pipe	75,832
Top section	4" Drill Pipe	0
	5" Drill Pipe	0

Depth of Interest	Section & Components	Cumulative tension at Top section(Klbs)	WOB(Klbs)				
			0	10	15	20	Critical buckling load(Klbs)
			Weight at point of interest				
20,000	BHA	0	0	-10	-15	-20	-258.827
	Horizontal	0	0	-10	-15	-20	
	Lower build	16.765	16.77	-6.77	-1.765	-3.235	-193.062
	Tangent	24.471	24.47	14.47	9.471	4.47	-104.585
	Upper build	42.45	42.45	32.45	27.45	42.45	-75.832
	Top section	58.86	58.86	48.86	43.86	38.86	

		WOB	0	20	25	30	
38,000	BHA	0	0	-20	-25	-30	-70.04
	Horizontal	0	0	-20	-25	-30	
	Lower build	16.42	16.42	-6.42	-8.58	-13.58	-57.702
	Tangent	21.1	21.1	-1.1	-3.9	-8.9	-35.052
	Upper build	42.08	42.08	22.08	17.08	-12.08	-25.412
	Top section	58.5	58.5	38.5	33.5	28.5	

CONCLUSION AND RECOMMENDATIONS

Torque and Drag is the major challenge faced by the operators while drilling an extended reach well. Torque and Drag have major influence in large lateral section wells due to large contact area of the drill string with the hole wall. It is noted that if drill string is lowered with rotation the drag values are reduced significantly in large amounts while the torque consumption increases. Since drag values are less the chances of buckling is also less but if buckling happens it can cause high fatigue failure in the drill string due to rotation while buckling. Buckling becomes highly significant and come in picture when the string is lowered without rotation into the hole this increases the axial drag forces and put serious limitation to depth due to buckling and lock up problems. But due to no rotation chances of drill string failure is less than with rotation. We have drawn and explained the same statement above through our case analysis and drawn similar inferences from it.

The project has a very wide scope in calculating the T&D values for different well trajectories and helps an engineer in calculating the well economics and compare different to obtain the optimum result.

RECOMMENDATIONS

- Use of rollers in the centralizers while drilling. Centralizers have maximum O.D than the tool joints and is contacted most with the hole resulting in high axial drag forces. With use of rollers in the centralizers at the point of contact with the well the axial drag is converted to rotational drag and the values of drag are reduced in much lower amounts.
- Use of light weight drill pipes in the horizontal section this reduce the side weight in the lower hole part in horizontal section and reduces the drag values.
- Use of mud lubricants that have the properties of providing a thick lubricant layer between drill pipe and hole walls reduces the T&D values.
- The tapered drill string also reduces the T&D values but when used with rotation because the critical buckling load of the less diameter drill pipe component is less and can be easily exceeded if using without rotation. But in rotation the axial drag is converted to rotational drag and the the buckling chances are very less.
- The BHA used while drilling should be such so that well quality is maintained and the tortuosity index remains low. The use of rotary steerable BHA is generally recommended

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