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T&D Challenges Running Casing in Extended Reach Wells

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Abstract

As horizontal and extended reach wells are becoming more commonplace and their horizontal sections increase in length, drilling engineers face additional challenges running casing into these wells. Frictional drag during casing running is often predicted during the planning stage as too great to allow casing to reach total depth without an innovative solution. This paper addresses the causes of excessive drag and solutions for overcoming them.

The physical phenomena that create drag in highly inclines wellbores are described. Five different methods used to improve the success of running casing to total depth are then studied, consisting of mud conditioning, casing flotation, axial vibration, rotation, and the use of casing swivels. Software assisted numerical analysis is used to study the impact of these drag reduction methods and means with which engineers can quantify the actual effect of these five practices are then discussed.

Ranges of open hole friction factors, lengths of air columns for floating casing, the impact of mud density, different rpms, and other variables are used to evaluate the reasonable impact of each of the drag reduction methods studied in this paper. Each of the five common methods evaluated in this study can significantly reduce drag for casing running, but depends upon their effectiveness and the specific sources of drag in the wellbore. Mud conditioning, for example, will reduce the friction factor more significantly in wells that have cuttings beds left behind from the drilling phase but will not alleviate drag resulting from doglegs both known or which occur between survey points.

This paper describes the causes of drag in horizontal and extended reach wells that result in challenges running casing to total depth, looks at common methods for remediating or alleviating the drag, and discusses the use of common software analytical techniques that can be used to not only predict, but also verify post-job the effectiveness of the chosen drag reduction solutions.

Introduction

Extended reach wells (ERWs) are generally accepted as having a horizontal departure twice that of the vertical departure or greater. This technique was initially developed in the 1980s and rapidly evolved during the 1990s. While ERWs still present significant challenges today, they are drilled regularly around the globe each year. Early successful ERWs were reported by, but not limited to, Mueller et al. (1991), Eck_Olsen et al. (1993), Ryan et al. (1995), Dolan et al. (1998), Naegel et al. (1998), Elsborg et al. (2005), McDermott et al. (2005), Algu et al. (2005), and Walker (2008, 2009).

Reported challenges include: Turner et al. (1989) described special difficulties in the early stage of ERW, including borehole stability, cuttings transport, data acquisition, drill string design, rig requirements, and well planning. Aarrestad (1994) addressed the various aspects of torque and drag problems encountered in drilling ERWS. Mason and Judzis (1998) presented a survey about the limit of ERW based on field case studies. Suggett and Smith (2005) presented a paper addressing ERW with the limit of rig capacity. Jellison et al. (2007) discussed drill string technologies involving advanced materials, ultra-high torque connection designs and other design considerations that are essential to achieving ERW targets. Rubiandini (2008) summarized the design techniques for ERW in deep water. Balandin (2010) discussed the option of using aluminum alloy drill pipe in ERW to reduce drag. Balandin (2010) discussed the use of Buoyant Aluminum Drill Pipe (BADP) in ERW to reduce pipe weight and push the limit of ERW. Gupta et al. (2014) described the key challenges in ERW including high torque and drag, wellbore positioning in a thin oil column, wellbore stability, long horizontal completions, and down hole tool telemetry.

According to the literature survey conducted, and previous practical case studies of ERWs, frictional drag during casing running is often predicted during the planning stage as too great to allow the casing to reach total depth without an innovative solution. The purpose of this study is to investigate the causes of excessive drag while running casing in ERWs and solutions for overcoming them.

Methods and Case Analysis

In this section, physical phenomena that create drag in highly inclines wellbores are described and studied. Five different methods proved to be effective in improving the success of running casing to total depth are presented: mud conditioning, casing flotation, axial vibration, rotation, and the use of casing swivels. For a better understanding and evaluation of casing running performance in ERWs, this paper also investigates the effect of varying fraction factors. This paper adopts software assisted numerical analysis in the investigation of these five methods. One practical Extended Reach Well from the field is used to support and validate the analysis. The basic well information is presented in the following table (Table 1).

Table 1: Basic Information of Extend Reach Well from Field

Description	Parameter	Data	Unit
Wellbore Interval (from Top Down)			
Casing 7 in, 26 lb/ft	ID	6.276	in
	MD	5600	ft
	FF	0.25	
Open Hole	ID	6.125	in
	MD	10,000	ft
	FF	0.30	
Pipes (from Top Down)			
Drill Pipe 3.5 in, 14 lb/ft	Length	5,400	ft
	Adj. Wt.	14	lb/ft
	OD	3.500	in
	ID	2.764	in
	Tensile Limit	343,988	lbf
	Torsional Limit	23,498	ft-lb
	FF Reduction (%)	0	
Casing 5 in, 13 lb/ft	Length	4,600	ft
	Adj. Wt.	13	lb/ft
	OD	5.000	in
	ID	4.494	in
	Tensile Limit	207,516	lbf
	Torsional Limit	22,548	ft-lb
	FF Reduction (%)	0	
Block Weight	Weight	30000	lbf

Mud Weight

This paper investigates the how the mud weight variation can affect the casing running to targeted depth in extended reach wells. In drilling operations, mud weight is a direct factor for maintaining mechanical stability, however few studies are found to investigate the effect of mud weight variation in Extend Reach Wells. The majority of fluid types for ERW are oil-based and synthetic muds.

Figure 1 presents the effect of mud weight on the axial force for running casing in ERWs. Mud weight variations have a more significant effect on the axial force in the curve section of a well where the side forces are the highest. As mud weight increases, the lifting buoyancy force makes pipe light, thus reduce the drag and hook load. While increasing mud weight may not be a practical drag reduction method, it can be seen that the lighter the pipe weight, the less buckling and greater the available hookload when running casing in an ERW. Figure 2 demonstrates how the various mud weight values may affect the side force in casing running of Extend Reach Wells.

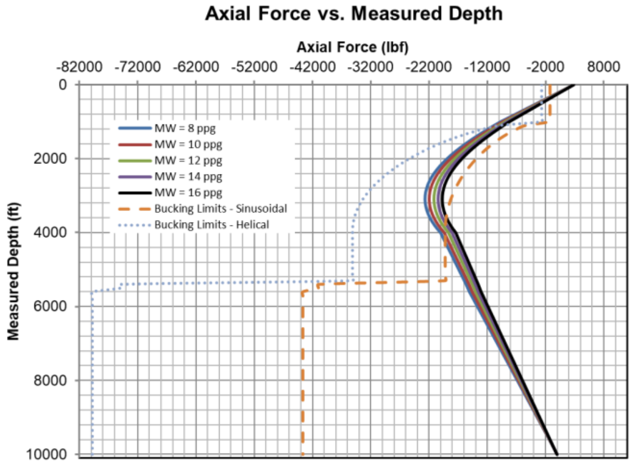

Figure 1: Axial Force vs. Measured Depth for Various Mud Weights

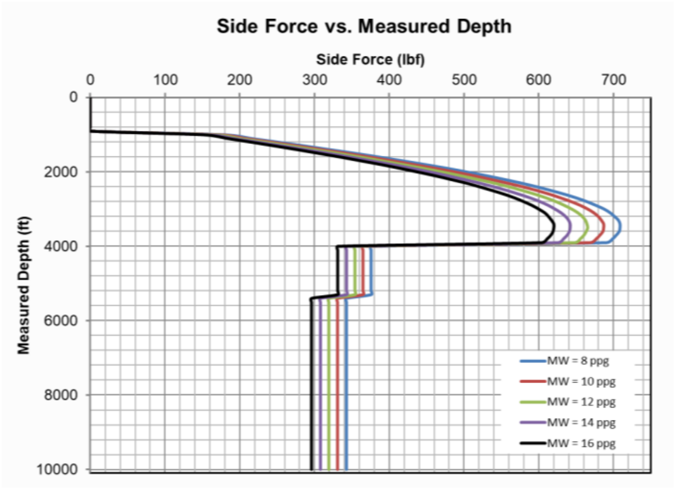

Figure 2: Side Force vs. Measured Depth for Various Mud Weights

Friction Factor

The friction factor is a combination of the coefficient of friction and a host of other factors that indicate wellbore quality. The friction factor has a significant impact on the success of running casing to TD in an ERW. The effect of friction factors is demonstrated in Figure 3 below. Negative axial force values represent compression, positive values represent tension, and the point at which the operational line crosses zero axial force is the neutral point in the string. Lower friction factors result in less drag, which allows for more available string weight to push casing out to TD. Practically speaking in ERWs, increased friction factors represent more challenging well conditions (i.e. higher concentration of cuttings or debris) and the compressive axial force becomes more severe.

In Figure 3, the larger friction factor may result in enough compression to generate sinusoidal or helical buckling. If the friction factor is greater than 0.2, a certain portion of casing becomes sinusoidally buckled. Once friction factor passes 0.3, a significant portion of the casing near surface becomes helically buckled.

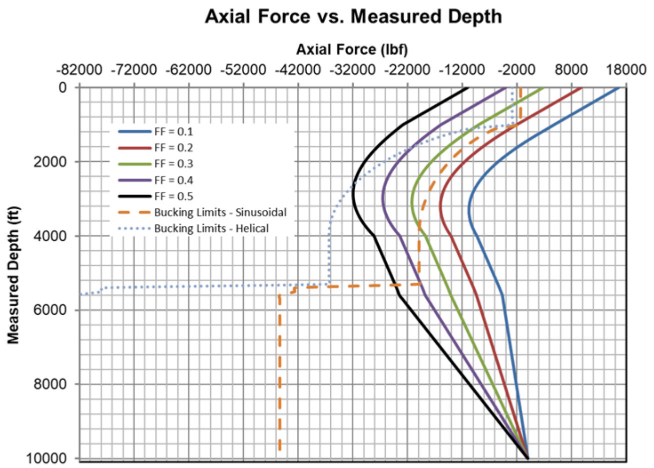

Figure 3: Axial Force vs. Measured Depth for different friction factors

Figure 4 illustrates the effect of varying friction factors in the open hole section on the hook load that begins at 5,800 ft MD. The hookload begins decreasing at 3,500 ft MD after running out into the lateral section of the well. Once it enters the open hole, larger friction factors increase the rate of loss of weight, and lower friction

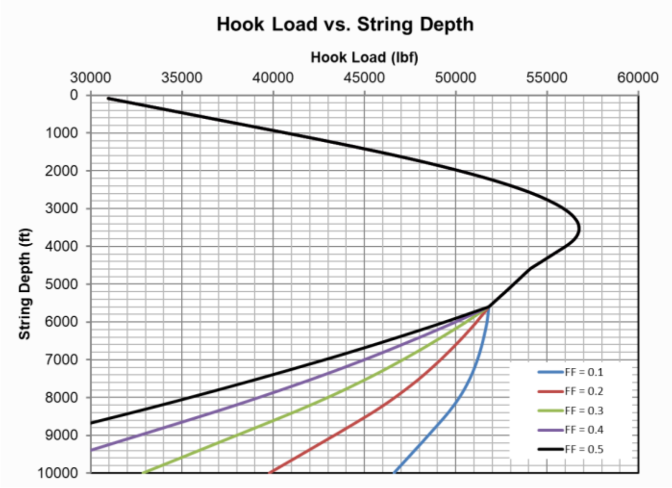

Figure 4: Hook Load vs. String Depth for different friction factors

Casing Flotation

When a certain portion of the casing, normally at the bottom, is filled with air, the volume of air results in an upward buoyant force from the displaced well fluid with only the weight of air to counteract it. This process is called casing floatation. Casing flotation can reduce drag forces, improving the ability to run casing in ERWs.

Figures 5 and 6 illustrate that the longer aired section length, the less the resulting axial and side forces. This is generally true for air section length up to the length of the lateral section. Using flotation to lighten the casing is an efficient way to reduce the frictional drag, which is achieved by lowering the normal force perpendicular to the contact surface. The other main advantage of this method is to reduce the buckling possibilities as you can see from the Axial Force graph (Figure 5). After using 2,000 ft of air at the bottom of the casing, buckling is eliminated in this well.

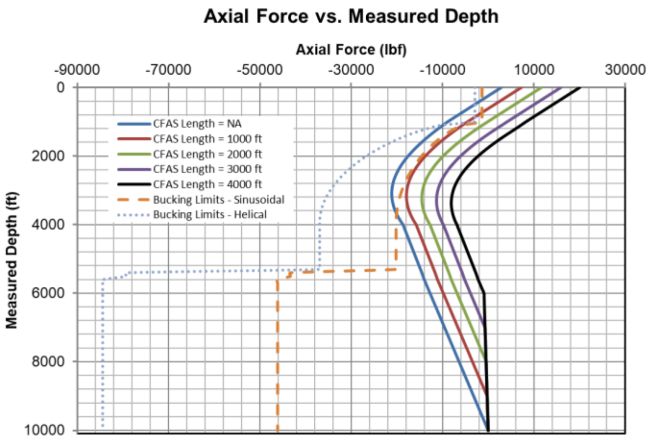

Figure 5: Axial Force vs. Measured Depth for Casing Flotation Air Section Length

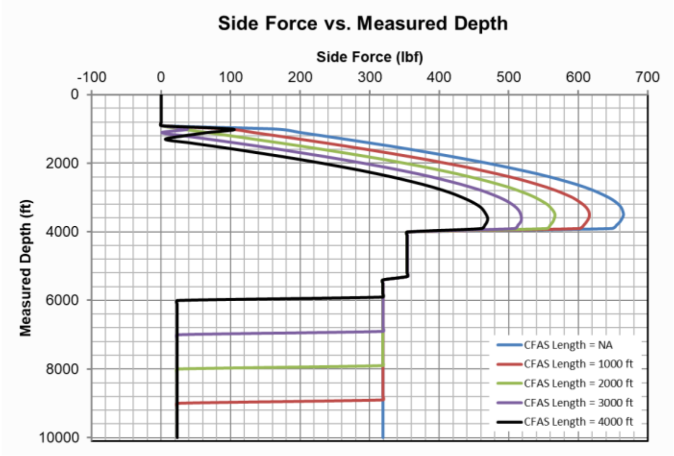

Figure 6: Side Force vs. Measured Depth for Casing Flotation Air Section Length Variations

The effect of casing flotation air section length to the hook load while running is shown in Figure 7. Up to the length of the lateral section, the length of air at the bottom of the casing is inversely proportional to the hook load when the string reaches TD. This relationship can be explained by that the weight is reduced and the drag is limited.

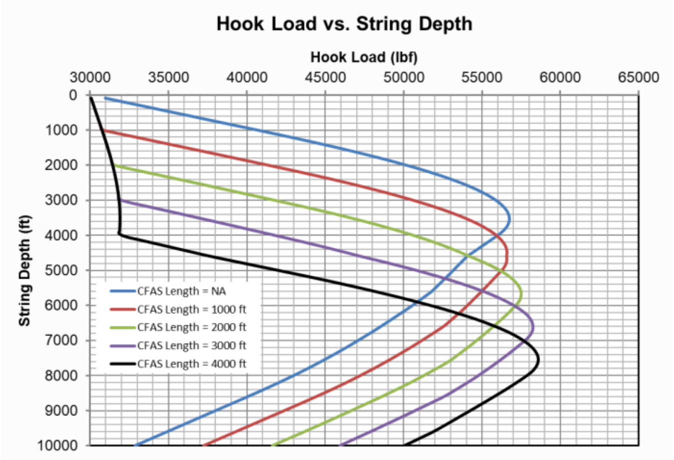

Figure 7: Hook Load vs. String Depth for Casing Flotation Air Section Length Variations

Rotation

Rotating while running casing is known to reduce drag. Figure 8 presents how the rotation speed affects the axial force along the measured depth. As the frictional resistance is changed from the axial direction to the circumferential direction, drag is reduced. This can also reduce the risk of buckling, as seen in figure 8 at 30 rpms and above.

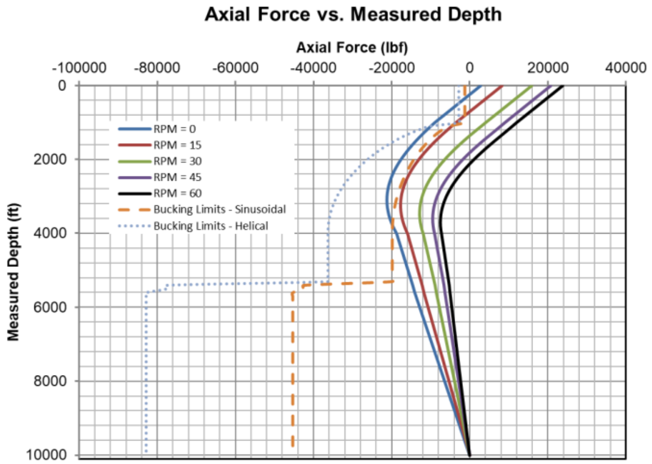

Figure 8: Axial Force vs. Measured Depth for various Rotation Speeds

Figure 9 shows hookload vs. string depth at various rotation speeds. Considering the rotation speed effect as the casing is run in hole, the additional weight per rpm diminishes with higher rotation speeds.

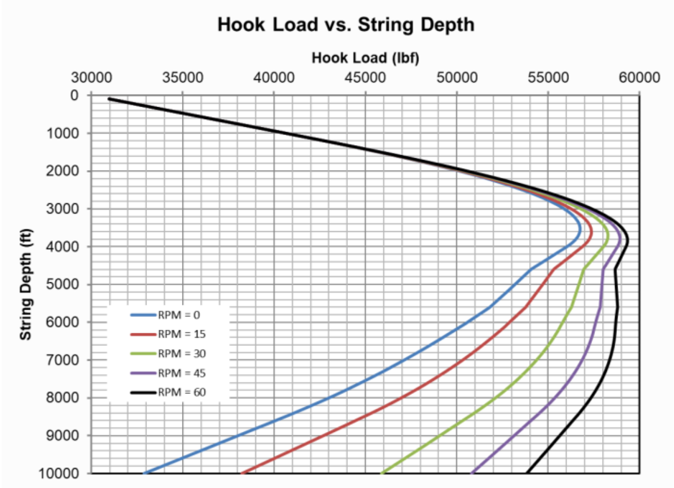

Figure 9: Hook Load vs. String Depth for various Rotation Speeds

Increases in surface torque for this well with increasing rpm are shown below in figure 10.

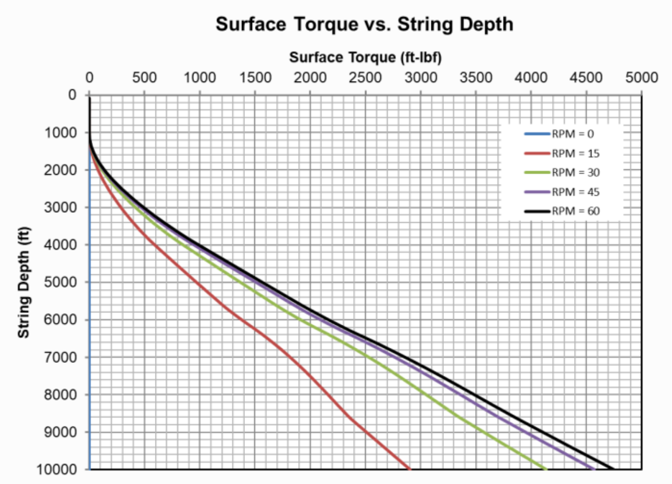

Figure 10: Surface Torque vs. String Depth for various Rotation Speeds

Casing Swivel Distance

A casing swivel is a tool that will allow the portion of the string above the swivel to be rotated while the string below the swivel does not rotate. This is commonly used to achieve some drag reduction without risking damage from rotating casing in a horizontal or highly deviated lateral.

Figure 11 shows the casing swivel effect on the axial force relative to the swivel's distance from the toe. The closer the swivel is to the bottom of the string, the closer the results are to the full string analysis run in section 2.4 of this paper. Variations in hookload based on swivel location are shown in figure 12.

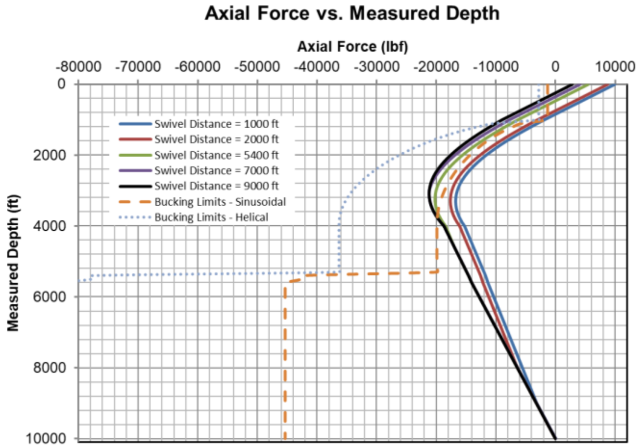

Figure 11: Axial Force vs. Measured Depth for Swivel Distance Variation

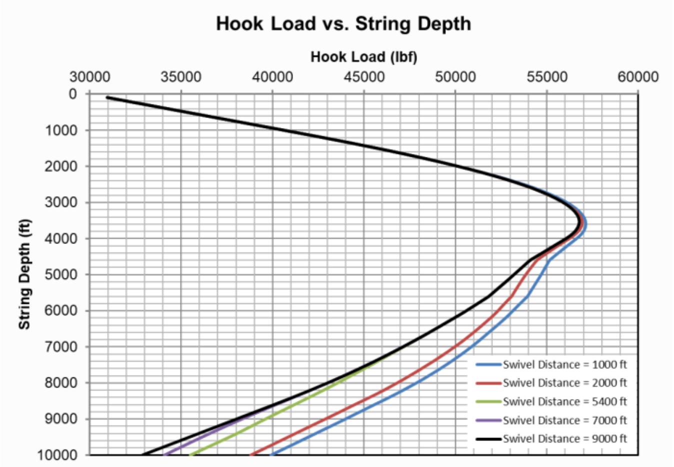

Figure 12: Hook Load vs. String Depth for Swivel Distance Variation

Torque at TD vs. the location of the swivel in the sting is shown in figure 13 below. Though the drag reduction benefit for rotating with a swivel is less than that of full string rotation, the torque generated is also smaller.

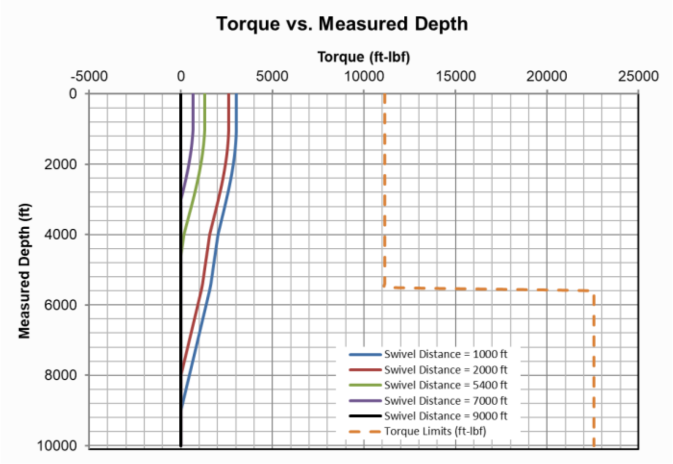

Figure 13: Torque vs. Measured Depth for Swivel Distance Variation

Discussion

This paper focuses on the main torque and drag challenges in casing running operations of ERW. The desired target total depth (TD) can be pushed further with less cost if we can solve the high torque and excessive drag force problems in ERW. The excessive drag in ERW is from the far reach section. As mud weight increases, the lifting buoyancy force makes pipe light, thus reduce the drag and hook load. It should be noticed the axial force is not quite sensitive to the change of mud weight. In our simulation, mud weight cannot solve the buckling problem since mud weight variation doesn't reduce the axial force at a significant level. However, the mud weight adjustment should work efficiently if combined with casing flotation system. Our simulation results already proved that casing flotation method could reduce the buckling possibilities as shown in Axial Force graph (Figure 5). When no aired section is used, the casing will be buckled; when we use 1000 ft o aired section, we basically eliminate the buckling. The main drawback of this method is related to collapse risk in ERW (Rae et al., 2004). The collapse may happen at a high chance if the casing (chamber) is fully filled with air. The light mud weight can be filled with the chamber to provide some inner pressure to overcome the outside pressure. Then, the section length, which is filled with light mud weight, can be adjusted to reduce the axial force without risks of collapse and buckling.

The friction factor is another vital factor in efforts to avoid buckling. If the friction factor is greater than 0.2, a certain portion of casing becomes sinusoidally buckled (Figure 4). It concludes that the small value of friction factor is preferred in casing running operations of ERW. To achieve this purpose, the oil-based mud (OBM) is proved to work better and more efficiently than water-based mud (WBM) because OBM is more lubricious WBM. In addition, the OBM can mitigate the wellbore instability risk caused by the chemical reaction between the long contact section between the mud and the formation in ERW. Considering drilling ERW in tight reservoirs, including shale gas/oil reservoirs, gas drilling is a new technique to lower the friction factor. Gas drilling is to use gas phase fluid as circulation fluid to transport drilling cuttings back to the surface, such as air, natural gas, and nitrogen. According to Glowka and Stone (1985), the friction coefficient is around 0.10 ~ 0.30 in gas drilling, which is much less than that with WBM in conventional drilling. In addition, it has been proved an efficient way to reduce the friction factor by adding some water to gas in the gas drilling.

Tripping speed and rotation should be considered together in the improvement of casing running in ERW. Proper design of tripping and rotation speeds can significantly reduce the axial force to get rid of buckling risk. The low tripping speed and high rotation speed are preferred to reduce the axial force and the side force. Casing rotation can reduce the axial drag. Even though the benefits of high rotation speed are obvious, they cannot cover the associated risks which are beyond the casing rates and the top drive capacity. There are mainly two methods for field operations to deal with the high torque from high rotation speed. The first way is to use high-torque resistant connections. Secondly, based on our simulation, casing swivel is a good tool when we still want to enjoy the benefits of high rotation speed. Casing swivel enables partially rotation of the casing, which can reduce the high torque and lower the high axial drag simultaneously. If compared to the connection rates and the top drive capacity, our calculation can use Torque profile (Figure 13) to determine the proper casing swivel location.

Conclusions

The main conclusions of this paper are summarized as below:

1. This paper describes the causes of drag in horizontal and extended reach wells that result in challenges running casing total depth.

2. Software assisted numerical analysis is used to look at common methods for remediating or alleviating the drag, including mud weight, friction factor, tripping speed, casing flotation, rotation, and casing swivel.

3. This investigation also discusses the use of common software analytical techniques that can be used

to not only predict but also verify post-job the effectiveness of the chosen drag reduction solution.

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