Torque and Drag Comparison in Directional Conventional, Slim Hole and Casing Drilling Method

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Abstract

Due to different location and field conditions, various drilling methods have been used to produce from oil and gas reservoirs. Three major operational methods defined as slim holes, conventional and casing drilling. Each type has some advantages and disadvantages. Despite many affecting parameters, torque and drag are two highlighted factors to choose best the drilling method. Torque and drag play significant role in the feasibility of drilling and final costs. In this study, the influence of two mentioned outstanding parameters are investigated to choose optimum drilling types with consideration of the same horizontal well trajectory and also without length and fatigue limitation. The well trajectory use in this study is real case located in Canada. Consequently, slim hole drilling shows minimum torque and drag values in comparison with conventional and casing drilling. Furthermore, casing drilling displays maximum drag in this case. Casing drilling methods shows lower torque value in vertical section of hole due to lower weight of drill collar but in bend section of hole increased. Final value of torque loss in casing drilling is maximum.

Introduction

Nowadays directional drilling is a challenging issue, this method is welcomed in the world especially in offshore fields. Using this method can help to product inaccessible fields like drilling an offshore field from shore or drilling a well into a residential field from far away. While directional drilling has many advantages, some issues can provide problems during drilling a well. Torque and drag are one of these problems that in some circumstances caused collapse of drill pipe, limited drilling length or waste energy and money. High dog leg severity and long horizontal departure caused high torque and drag lost in the drilling system. In drilling industries various type of well are used; three of the more interesting types of well will be explained here.

Conventional (rotary) drilling is one of the oldest methods used from the beginning in the industry. In this method a well will be drilled with normal equipment and according to conditions it will be completed as an open or cased hole. The simplicity of this method makes it the most popular in the world.

Casing drilling is the newest method used in drilling industries. This method combines the drilling and casing steps of well construction into a single process that improves drilling efficiency. Casing drilling can significantly improve drilling performance when drilling take place across pressure transitions. Overcoming pressure transition issues help to solve lost circulation and well control problems; also it eliminates at least one error that makes this process more economical.
Casing drilling has some disadvantages like using special equipment, whereas the more annoying issue is limiting the application in directional drilling.
Because the diameter of casing is more than the drill pipe and the flexibility of it is less, high dog leg severity can cause failed drilling process [3] [5] [6] [11].

Slim hole drilling is a method that is used by mining industries but also in the petroleum industries because of its advantages. A slim hole drilling significantly reduces the costs; and it is attributed to saving money in casing, rig site, disposal cost, environmental impact and nuisance, cutting the volumes of muds, cement etc. The major concern in using the slim hole drilling method is drill string failure associated with the use of small diameter tubing. The reduced size slim hole drill pipe, can significantly reduce torque transmission capability. Kick detection, tool joint failure, decreasing penetration are the other disadvantages of this method [2] [9] [10].

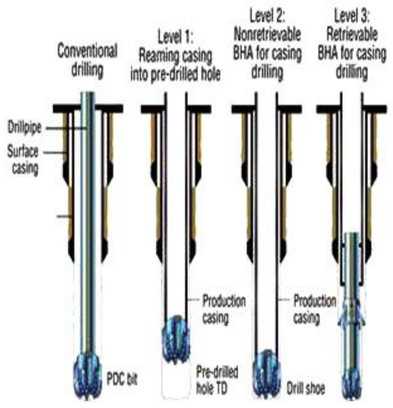


Figure 1 : Conventional well vs. Casing drilling well

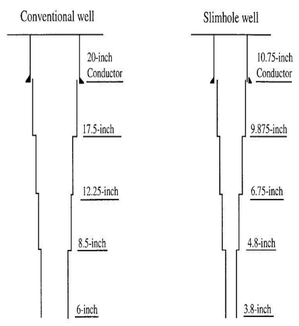


Figure 2 : Conventional well vs. Slim hole well

The explained drilling methods will be compare due to below forces.

Drag is the difference between free rotating weight and the force required to move the pipe up or down in the hole. Drag force is used to overcome the axial friction in the well. This is a phenomena associated with deviated wells.

Torque is a quantity of how much a force acting on a drill string causes that drill string to rotate. The torque is used to overcome the rotational friction in the well and on the bit. Torque will be lost along a drill string so that less torque is available in the bit for destroying rock. Perfect vertical well has zero torque loss; except for a small loss due to viscous drag from mud.
Generally high torque and high drag occur together but these forces are not the only forces affecting on the drill string.
Because of immersing the drill string in mud, the weight of drill string will be reduced due to Buoyancy force, also friction force is always present in real system that resists movement and rotation of the drill string.

Methodology
Drilling a directional well is more complex than vertical well because of the angle and direction of the well. In this paper a directional well divided into two sections. The first section refers to the straight section of well and second one refers to the curved section of the well. Each section will be analyzed separately and finally the summation of the forces of each section is equal to the force that is acting on the drill string.

Straight section
Drag force that acts on straight section of drill string [1], will be calculated by below equation:

$$F_n = \sum_{i=2}^{n}\{\beta w \Delta L \times (cos\alpha \pm \mu sin\alpha)\} \qquad \text{eq. (1-1)}$$

When the friction coefficient is equal to zero, the Equation shows the static weight of the drill string in a straight section for different drilling operations.
Also the sign "+" means that the pipe is pulled upward and the sign "-"means that the pipe is lowered downward.

Torque that acts on drill string [1] is defined as:

$$T_n = \sum_{i=2}^{n}\{\beta w \Delta L r sin\alpha \times \mu\} \qquad \text{eq. (1-2)}$$

The above equation shows torque loss along the drill pipe and can be considered independent of the direction of rotation.
For inclination equal to zero as it is in a vertical section; no torque loss is present due to the negligible value of the normal force. For inclination equal to 90 degree as it can be seen in a horizontal section, the maximum torque loss will be occur due to maximum normal force.
Curved section
Drag forces that act on the curved section of drill string will be calculated from equation (1-3).

$$F_n = \sum_{i=2}^{n}\left\{F_{i-1} \times e^{\pm\mu_i|\theta_i|} + \beta_i w_i \Delta L_i \times \left[\frac{sin\alpha_i - sin\alpha_{i-1}}{\alpha_i - \alpha_{i-1}}\right]\right\} \qquad \text{eq. (1-3)}$$

And Torque loss in the curved section defined as:

$$T_n = \sum_{i=2}^{n}\mu_i \times r_i F_{i-1}|\theta_i| \qquad \text{eq. (1-4)}$$

The case that will be discussed here is a two dimensional S-shaped well. Figure 3 shows an S-shaped well that is drilled in a vertical plane.
The total length is 2111 m. The well is filled with 1.3 SG drilling mud and the coefficient of friction is estimated to be 0.2. The bottom hole assembly (BHA) starts out just below the drop-off section, and is vertical. For this case there is no change in azimuth, and the dogleg becomes equal to the change in inclination.
In conventional drilling the drill string consist of 161 m of 8" drill collars and 1950 m of 5" drill pipe. The drill collar radius is 0.1 m, and the drill string connection radius is 0.09 m.
In slim hole drilling, the drill string consists of 161 m of 4 7/8" drill collars and 1950 m of 2 7/8" drill pipe. The drill collar radius is 0.062 m, and the drill string connection radius is 0.061 m
In casing drilling the drill string consist of 6.625" casing. The casing radius is 0.168 m.

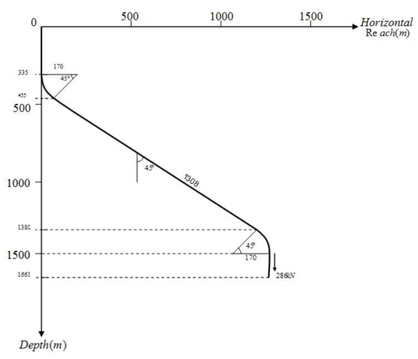


Figure 3 : An S-Shaped Well Trajectory

Table 1 : Specification of Drilling String

Drilling Method	Conventional Drilling	Slim Hole	Casing Drilling
Drill Pipe Length (m)	1950	1950	-
Drill Pipe Radius (inches)	5	2 7/8	-
Drill Pipe Weight (kN/m)	0.285	0.152	-
Drill Collar Length (m)	161	161	-
Drill Collar Radius (inches)	8	4 7/8	-
Drill Collar Weight (kN/m)	2.13	0.728	-
Casing Length (m)	-	-	2111
Casing Radius (inches)	-	-	6.625
Casing Weight (kN/m)	-	-	0.467

Results
According to drag equation in each section and considering specification of each method, the results can be seen in figures below.
Drag force in static weight, hoisting and lowering in each case is presented. In the slim hole method, because of using drill pipe and drill collar with less diameter than the conventional method, the weight of drill string reduces significantly and therefore drag force will be reduced; as you can see in the force diagram. Using smaller drill pipe in the slim hole method helps to reduce drag force but pressure tolerance is reduced.

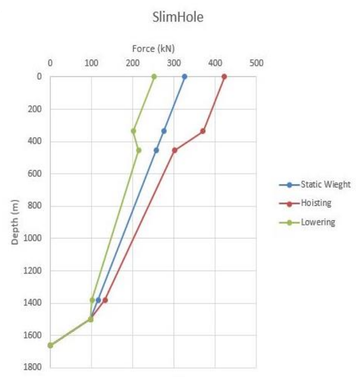


Figure 4 : Drag Force in Slim Hole Well

In the casing drilling method, because of the use of casing instead of drill pipe and drill collar, the system weight will be increased. Casing has more weight in compression with drill pipe and less weight in compression with drill collar but this weight is constant during the drilling process although the amount of total weight is more than that in the conventional method. This increase in amount of weight resulted in increasing the drag force.

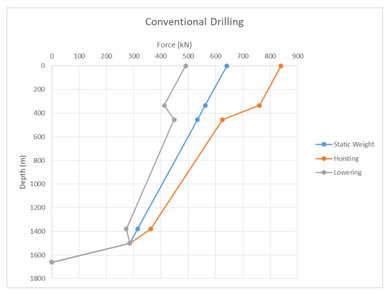


Figure 5 : Drag Force in Casing Drilling

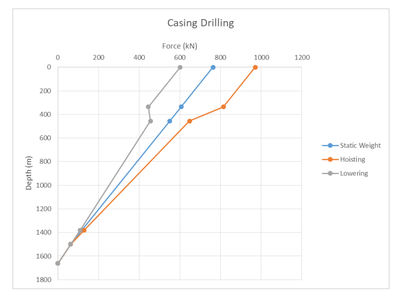


Figure 6 : Drag Force in Conventional Well

Also Torque in 3 cases determined and compression in a chart.
As can be seen in the figure 7, torque in the slim hole is less than the other holes but the capability of the drill string is less and the possibility of failure is more likely. This reason causes a limitation in the drilling length.
Casing drilling in first high dog leg severity behaves similarly to slim hole. This section shows that the torque is less than the conventional method and it can be due to less weight of casing compared with the drill collar; also lower torque in an inclined section is due to this reason. In second high dog leg severity due to less flexibility of casing than drill pipe, torque will be increased significantly even more than conventional drilling. This sharp increase in this section can be the reason of failure in the drilling process.

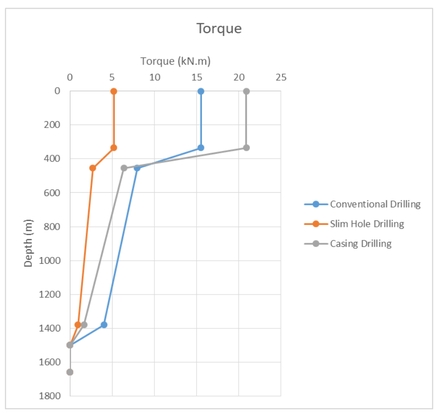


Figure 7 : Torque Comparison

Conclusion

Slim hole with its specification can be effective and economic in the field but length of well must be consider due to the stability of this method
Casing drilling technology is one of the best recent drilling technologies. It can reduce the time and cost of drilling. Also it reduces the across pressure transient risks, but in directional drilling, this method shows some weakness especially when the rate of building angle increase.
Increasing in build or drop section number caused a significant increase in torque.
Weight of drilling string is important because this is a major factor that affects parameter on drag force. This force in pulling down and pulling up drill string is important.

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