TORQUE AND DRAG MODELLING FOR THE WELL F-10

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Abstract

Many oil and gas companies now drill horizontal and deviated wells for a variety of reasons. Horizontal wellbores are very helpful in unconventional reservoirs such gas shale and tight formations, allowing for increased production from these sources. One technological problem that must be thoroughly investigated throughout the design phase is the uptick in torque and drag forces downhole in deviated borehole trajectories. Torque and drag in business have historically been represented using a number of different approaches. The use of viscous fluid flow and soft string, stiff string approaches are among them. Since the drill string is modelled as a cable and is always assumed to be against the low side of the wellbore in the soft string model, drill string stiffness is disregarded. Stiff string models take into consideration the radial clearance in the wellbore in addition to the drill string's stiffness and bending moment. The normal component of fluid pressure on the drill string varies during drilling because fluid flow is not constant. The tangential component of the fluid flow is caused by the viscous drag on the drill string.

Study was conducted to identify the best approach to modelling torque and drag for the F-10 well in the Volve field and comparable wells in the future, and the results of that research are presented here. The F-10 well was drilled in a northwesterly direction to confirm the presence of petroleum in Middle Jurassic reservoir rocks, thereby revealing further potential resources for the Volve field (the Hugin formation). Studies into both soft and stiff string methods will be conducted. The importance of taking viscous drag into consideration will also be evaluated.

The concepts torque and drag, soft string, stiff string, and viscous fluid flow are discussed.

Keywords: Torque and Drag, Soft String, Stiff String, Viscous Fluid Flow

1. Introduction

When a borehole is drilled at an inclination relative to the true vertical, friction and normal forces are generated due to the contact between the drill string and the drill hole. Torque and drag create friction and normal forces that push against the drill string's forward motion. To spin the pipe, more moment force, or torque, is needed, and to move the pipe up or down in the borehole, more force, or drag, is required, both due to frictional forces and contact loads [1].

The amount of normal and frictional force experienced while drilling is affected by the drilling parameters and the surfaces hit. Several elements, such as the drilling mud, the well design, the surfaces encountered in the hole sections, and the tubular structure, influence the coefficient of friction and normal forces. Tubulars will make touch with the casing in a cased hole, but with the formations in an open hole. Cased holes typically have friction coefficients of 0.25, whereas open holes often have friction coefficients of 0.35 when utilizing water-based mud for drilling [2].

It's possible that the amount of torque and drag you feel will depend on the drilling technique you're using or the nature of the work at hand. Drilling modes, or how the drill string travels, may be either rotary or sliding. During a sliding operation, the drill string travels axially up and down the borehole, whereas during a rotational operation, the drill pipe rotates around a point in the borehole. Drag forces are increased when the drill string is slide, although torque is little affected [3]. Tripping in and out of the well is one of the many processes involved in drilling.

Based on the equations presented in Section 2, Johancsik et al. [4] developed the soft string model to simulate torque and drag during well-digging. The soft string model assumes that the whole drill string is pushed up against the wellbore's low side, independent of the drill string's actual stiffness. Most of the contact forces occurring on the wellbore are shown in models to be exerted on the drill string, which is depicted as a cable formed of separate segments [5].

To better represent downhole circumstances, both the soft string model and the stiff string model were created. According to McCormack et al. [5], stiff string models consider not only the radial clearance in the wellbore, but also the stiffness and bending moment in the tube. The authors also argue that the inclusion of more variables in the stiff string models does not automatically make them more accurate than the soft string models. It depends on the characteristics of the well as to whether a soft string model or a stiff string model is used. Use a stiff string model for well trajectories with many sharp turns, severe doglegs, or stiff tubulars [5].

Although intricate, fluid flow's impacts on torque and drag are often neglected in models. An otherwise constant component of fluid pressure on the drill string is lost as a result of the drilling process. As a result of the viscous drag experienced by the drill string, the tangential component of the motion is also contributed by the fluid flow [6]. [7] Determine the force increase due to viscous drag by performing the following steps:

$$\Delta \mathrm{F} = \frac{\Delta P\pi\left(Dh^2 - Dp^2\right)DP}{4(Dh - Dp)} \tag{1}$$

where N is in newtons, P is in pascals, Dh is in meters, and Dp is in meters. The rheological model used affects all of these parameters (m). Applied Drilling Engineering [8] discusses the use of several rheological models to determine the amount of annular pressure lost during drilling. Given that the pipe must be turned in order to measure viscous drag, this is an indirect measure.

Calculating the torque applied to the pipe because of viscous drag looks like this [7]:

$$\Delta T = \tau_t 2\pi L\left(\frac{Dp^2}{2}\right) \tag{2}$$

Pipe length L is the torque in Newton-meters (Nm), and t is the shear stress in Pascals (Pa) calculated using the rheological model (m). Applied Drilling Engineering [8] provides further information on how to compute shear stress for a wide range of rheological models.
The F-10 well is located in the southernmost portion of the Norwegian sector, and this article describes the calculations of torque and drag that were run on it.

2. Calculating Torque And Drag

Well friction equations for deviated wellbores were developed by Johancsik et al. [4], who also performed the first comprehensive analysis of torque and drag. Some researchers hypothesised that the sliding friction forces produced by the drill string's contact with the wellbore were a primary cause of both torque and drag. Sliding friction force was modelled by Coulomb as a function of normal contact force and coefficient of friction between the contact surfaces. The normal force may be determined using the formula:

$$F_{n=\sqrt{(F_t\Delta\propto\sin\theta)^2+(F_t\Delta\theta+\mathrm{w}\sin\theta)^2}} \quad (3)$$

is the inclination angle (in degrees), is the dogleg angle (in degrees), Fn is the normal force (N), Ft is the tensile force (N), and w is the weight of the pipe (in kilograms) (N). The increments in tension are then calculated using the following equation:

$$\Delta F_t = w\cos\theta \pm \mu F_n \quad (4)$$

how much friction there is, Drill string movements going up are indicated by a plus sign (+), while those going down are indicated by a minus sign (-). And here's how you figure out that torsion increase, too:

$$\Delta M = \mu F_n r \quad (5)$$

in which torque is (M) and pipe's radius is r. Taking into consideration the upward acting mud pressure as the drill string descends into the hole, Sheppard et al. [9] modified the model of Johancsik et al. [4] into a more typical differential form. He used effective tension instead of actual stress since it is the sum of genuine tension and mud pressure.
These two publications have had much use and development since their first publication. In a more recent mathematical analysis of prior friction models, Aadnoy and Djurhuus [10] developed a universal, simpler model with just two equations (one for rotating friction (torque) and one for pulling friction (drag)) that is applicable to a broad range of well geometries (vertical, build up, drop off, and straight sections). Despite their progress, however, these techniques remained relied only on a two-dimensional plane. The solutions provided here have been extended by Aadnoy et al. [11] to include a three-dimensional geometry.

F-10 WELL

StatoilHydro Petroleum AS, the holder of production license 046, has finished drilling observation well F-10, which also held an exploration objective. Lower Triassic Smith Bank formation, reached after drilling to a vertical depth of 2963 meters below sea level. When the well was permanently plugged, it was left abandoned. Well F-10 in the Volve field was drilled by the Maersk Inspirer in 91 meters of water.

About seven kilometers to the northeast of the Sleipner A facility in the North Sea, the dry well was drilled diagonally/horizontally to an exploration target. [12]. On April 7th, 2009, a 26" surface hole was bored in a directed fashion to a depth of 1400mMD, and then cased with a 20" casing. A 17 -1/2" intermediate directional hole was drilled, bored to 2007 and cased with 13 3/8" casing. In order to reach MD 3439, a further 12 14" intermediate hole was bored and 9 5/8" casing was utilized for its completion. After that, a vertical hole 812" in diameter was bored at a TD of 5331mMD. The TD bottom hole was located 760 meters west (260 degrees) of the surface location [13].It can be seen in the vertical section of F-10 displayed in Figure 1 that the wellbore trajectory is of the build, hold, and drop kind. Once the KOP is reached at 351mMD, the well will be drilled at an angle to reach the desired depth of 5331mMD.

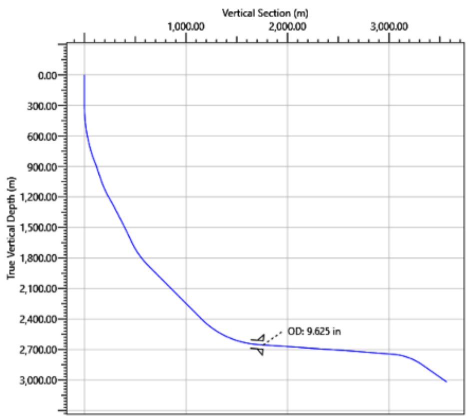

Fig. 1 – Vertical Section of F-10.

Figure 2 displays a maximum rise of 2.40 degrees per 100 feet and a maximum fall of 3.02 degrees per 100 feet. The maximum angle of the trajectory, 85 degrees, was obtained at around 3390 m MD and stayed constant until 4690 m MD. This greatest angle of inclination is now about 88 degrees. Starting at an initial altitude of 5017mMD, the trajectory gradually dips at a rate of 3.02°/100ft. In order to get ready for a vertical drill to TD at 5331mMD, the well was kept running (3017mTVD).

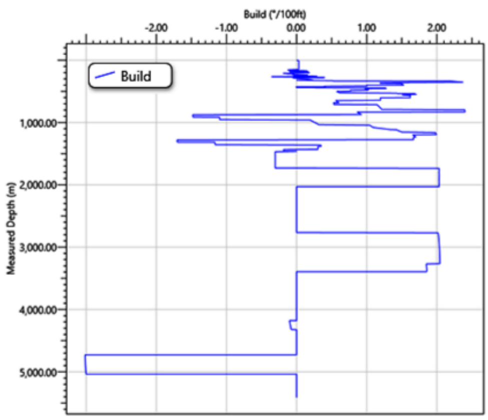

Fig 2 - Build angle over well trajectory.

The outcomes of a simulated drill at well F-10 are shown in Table 1. The oil-based mud used to drill the 81/2" hole had a density of 11.02 ppg (1.33SG), and friction factors of 0.25 for cased holes and 0.35 for open holes were utilized, as suggested by McCormack et al. [2].

Table1 - Modelled hole sections for F-10.

Section Type	**MD (m)**	**ID (in)**	**Effective Hole Diameter(in)**	**Friction Factor**
133/8”,72ppf,P- 110Casing	2607.00	12.347	17.500	0.25
95/8”,53.50ppf,C- 95 Casing	3441.00	8.535	12.125	0.25
Open Hole	5331.00	8.500	8.500	0.35

3. Modelled Drill String

Well F-10's simulated drill string utilized to attain TD is shown in Table 2. Using information given by equinor and StatoilHydro Petroleum AS for the Volve field, we were able to choose components from the Wellplan library for the simulated drill string. Assemblies with 8 1/2" bottom holes are seen in [13].

Table2 - Modelled drill string for F-10.

Drill String Component	MD (m)	OD (in)	ID (in)	Weight (including connections) (ppf)
Drill Pipe	3199.20	5.356	4.670	24.70
Drill Pipe	5199.20	4.860	4.276	19.50
Heavy Wall DrillPipe	5217.20	5.00	3.375	57.12
Jar	5226.70	6.50	2.75	86.96
Heavy Wall DrillPipe	5254.70	5.00	3.375	57.12
Jar	5263.42	6.625	2.75	84.00
Heavy Wall DrillPipe	5290.42	5.00	3.375	57.12
Stabilizer	5291.94	6.75	3.000	147.01
LWD Tool	5301.39	6.75	2.810	90.32
LWD Tool	5308.46	6.75	4.870	90.51
MWD Tool	5317.36	6.75	5.109	84.44
LWD Tool	5325.36	6.75	2.000	107.14
Stabilizer	5326.89	6.75	2.813	83.26
Mud Motor	5330.64	6.75	2.630	63.88
PDC Bit	5331.00	8.50	-	250.00

The models included the following aspects of drilling:

With a bottom-mounted rotational force,25 kips WOB and a bit torque of 12,000 ft-lbf. With a 25 kips WOB and 12,000 ft-lbf torque at bit, the rotor is spinning off the bottom. Using a 25-kips WOB and a 12,000 ft-lbf bit torque, a driller slides down a borehole. The round trip was modelled at 60 feet per minute and zero revolutions per minute.

Information from the Volve field's daily drilling reports was used to determine the WOB and torque at bit settings for TD drilling [13]. All of the speeds and rpm used for tripping in and tripping out were chosen at random. In the following paragraphs, we will show how to simulate a drill string taking into consideration the soft and stiff approach and the influence of drilling fluid using Halliburton's Landmark WELLPLAN tool [7].

Soft string approach with no viscous fluid effects

Scatter plots of cumulative torque and effective tension versus MD are shown in Figures 3 and 4 for a soft string method to show that they are unaffected by viscous fluids. Both photographs support the findings of Maehs et al. [14], who found that the drill string is subjected to the greatest stress near its top. This occurs because these forces build up from below.

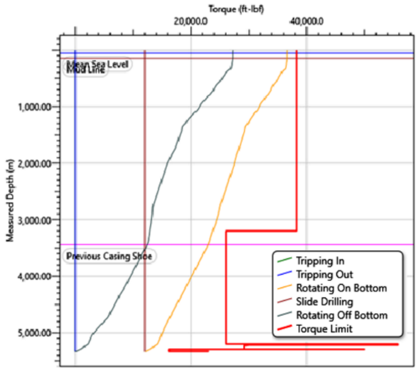

Fig3 -The soft string method is used to construct the torque plot, without the effects of viscous fluids.

Torque builds up at 5017 mMD for both bottom rotation and top rotation, as seen in Figure 3, especially between 4730 and 5009 mMD, 1717 and 2040 mMD, and 1343 and 338 mMD. Figure 5 depicts the side force per normalizing length, which explains these trends (30ft). Between these depths, the side force increases, as seen by the graph. The pace of development and drop down accounts for the observed rise in side pressures between these depths (Figure 2). There is a 2.37°/100ft increase and a 1.70°/100ft decrease between the depths of 338 and 1343 meters marine depth (MD), and between the depths of 1717 and 2040 MD, respectively. The consistent degree of side forces and the lesser rise in torque forces may be explained by the fact that the build rate is 2.02°/100 ft between 2029 and 2751 mMD, 3399 and 4717 mMD, and 5044-5190 mMD, respectively. This indicates that the deviation is a source of the side force and, by extension, the enhanced torque. Equation 5 provides mathematical proof that an increase in normal force also increases torque, corroborating these results.

The absence of torque is also seen during in and out tripping, as shown in Figure 3. This is correct, since the pipe is not spinning. The formulas provided by Aadnoy and Djurhuus [10] show that when the rotation of the pipe is zero, the friction angle " equals zero, and thus there is no torque. The torque for slide drilling is also maintained at 12,000 ft-lbf, just like the bit torque. Since the ceiling does not move, the torque for the bit remains constant as well.

Figure 4 displays how the effective tension forces build up differently for various drilling procedures, some of which include tripping out, rotating off bottom, tripping in, rotating on bottom, and slide drilling, all of which also raise as side forces rose in fig 5.

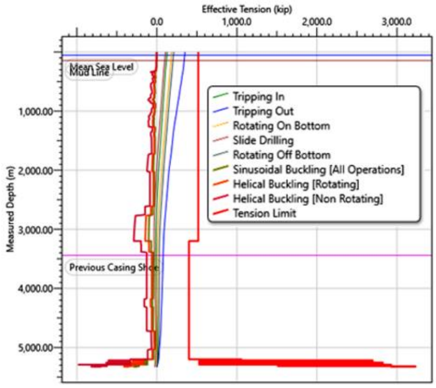

Fig 4 -The effective tension plot was determined via the soft string method, which ignored the effects of viscosity.

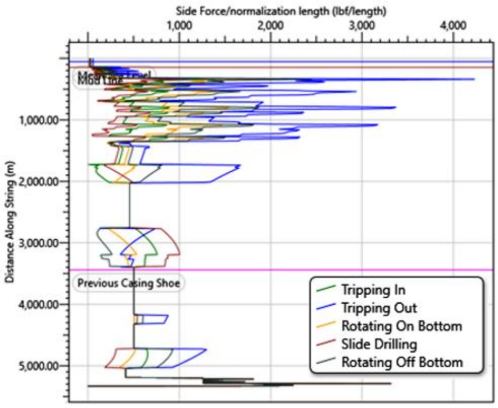

Fig 5 -Extracted from a soft string technique that ignores the effects of viscous fluid, a plot of the side force as a function of normalized length.

To see how the normal force increases with upward drill string movements and decreases with downward motions, consider Equation (4).

The failure limits of the simulated drill string are not exceeded, as shown by two statistics (torque and effective tension), therefore the drill string will not buckle, twist off, or break.

Stiff string approach with no viscous fluid effects

A stiff string approach was used to depict the cumulative torque and effective tension vs MD (see Figures 6 and 7) without viscous fluid effect. Torque and effective tension trends are comparable across the soft string and hard string strategies, with only modest variations in downhole forces. Plus, the drill string can't break, so that's never an issue either. What we learn by comparing the two methods is as follows.

Torque peaked at 1039.4 ft-lbf while spinning on bottom and 1125.7 ft-lbf when lifted off bottom. There was no change in the maximum torque required to drill a slide, trip it out, or trip it in.

During slide drilling, maximum effective tension was increased by 1.8 kips, while tripping out lowered it by 9.7 kips and tripping in increased it by 1.7 kips. Maximum effective tension needed for bottom rotation remained unaffected.

The maximum drag during take up was lowered by 6.4 kips, and the maximum drag during slack off by 0.9 kips.

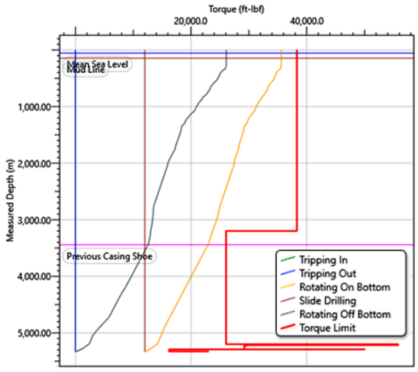

Fig 6 - Torque graph derived using a stiff string model, which ignores the effects of viscous fluids

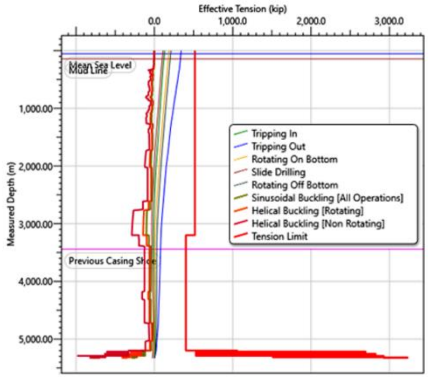

Fig 7 -The effective tension plot was determined via a stiff-string method, which ignored the effects of viscous fluids.

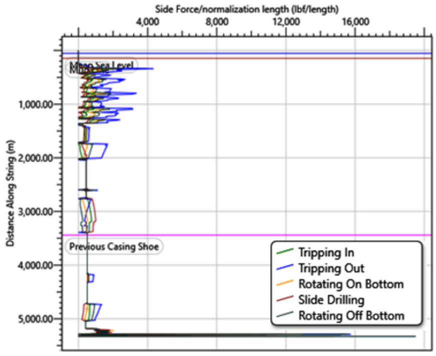

Fig 8- Diagram depicting the normalized side force as a function of length, as estimated by the stiff string method, which ignores the effects of viscous fluids.

Forces are reorganized in Figure 8 as a result of a change in the lateral forces. The side forces are affected when the drill bit is no longer expected to stay on the low side of the borehole wall, since this assumption is no longer valid once the stiffness of the drill string is considered.

Modelling with viscous fluid effects

The following findings were found for the maximum forces experienced in the well utilizing the soft string and stiff string techniques when viscous fluid effects were considered.

When spinning both on and off the bottom, maximum torque rises by 468.7 ft-lbf. Drilling with slides and tripping in and out proceeded as previously.

Whereas tripping out, maximum effective tension increased by 4.8 kips, while tripping in saw a loss of 3 kips. Not a single thing about how slides are rotated, drilled, or drilled into was altered.

Maximum drag has been increased by 4.8 kips during the pick-up phase and by 3.1 kips during the slack-off phase.

The consequences of a viscous fluid remain the same regardless of the modelling approach chosen (soft string vs. stiff string).

When viscous fluid effects are taken into account, there is a little modification to the torque and drag, but the effective tension graph maintains its general shape.

4. Conclusions

In the case of Well F-10, we observed that the downhole force that has been accumulated is directly proportional to the orientation of the well. The rate of change fastest in torque and effective tension prompted when build up and drop off rate is increased. As for the drill string snapping, it was also ruled out by the simulations.

We find that both the soft string and the stiff string models get precise results when assessing the torque and drag of the F-10. Since the stiff string method more accurately takes into consideration the stiffness and bending moment in the drill string, it is advised that it be used to estimate torque and drag for wells with comparable characteristics. Viscous fluid had no effect on the torque and drag models used to simulate the well. Each of the maximum forces experienced downhole, with the exception of the maximum effective tension and drag for tripping in, increased as a result of the impacts of viscous fluids.

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