Torque Reduction while Drilling With Casing

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Abstract. Currently, we have been witnessing the increasing number of problems in drilling caused by certain challenges in drilling through depleted reservoirs, complicated geological settings, and fast-growing technology of extended reach drilling. One of the methods used to solve the problems is casing-while-drilling. The authors have been studying the difficulties occurring while using this method with a special focus on the issue of torque increase while rotating a casing string at an excessive speed. The paper presents calculations of the torque taking into account the friction coefficient. As an effective solution to reduce the torque a new centralizer has been designed in the laboratory of the Department of Oil and Gas Well Drilling of Almetyevsk State Oil Institute. While performing casing drilling operations a new centralizer with roller balls attached makes it possible for rolling friction to be replaced with sliding friction and, thus, prevent thread stripping.

1. Introduction
There appears to be a tendency for drilling hazards increase due to drilling wells in depleted fields, so called stripper wells, in difficult geologic conditions, and horizontal extended reach wells. One of the problems encountered when drilling and constructing horizontal wells is associated with unstable rock caving in while penetrating a pay zone. The common practice used to control sloughing-in of hole walls involves the following: tripping for replacing BHA for EZReam; flushing the hole with hi-vis pills; and drilling mud weighting to prevent borehole from caving in.

Moreover, there are pressure drops and a swabbing effect in the borehole which are the problems that occur while tripping drill pipes. The pressure drops may cause circulation loss due to discontinuity of the permeable and fractured formations. The borehole pressure is reduced with swabbing but still influences the further swabbing and the borehole instability. Borehole rock caving-in occurs when the drilling-fluid pressure is too low to maintain the structural integrity of the drilled hole. These challenges are associated with significant time and money investments [1,2].

2. Overview of the Project
Casing-while-drilling is considered to be one of the techniques to solve the problems related to the preparation of the horizontal section to running and cementing of the production string. It encompasses the process of simultaneously drilling and casing a well, using the active casing and thus optimizes the production. Casing drilling has been employed in many countries as an effective method of reducing the overall drilling costs by reducing drilling time and drill-string problems encountered during conventional drilling process. In addition to productive time losses during drilling and tripping operations, unscheduled events can make the drilling process even more inefficient and even lead to losing the well.
Currently, Baker Hughes, Weatherford, Schlumberger and Halliburton companies, cooperating with Russian Gaspromneft and LUKOIL, have reported of their successful operations in the Orenburg oil and gas condensate field and in the Bayandykskoye field. Their achievement was made possible due to using the Direct XCD casing-while-drilling drillable alloy bits. Direct XCD bit enabled effective casing while drilling under complicated conditions. As a result, it took 30.7 hours versus the 31 days previously required to run the casing, a well construction time was reduced by an average of 10 and 16 days accordingly[3,4,5], and good results were achieved in controlling the string with sticky, difficult open hole.

In 2014, with the aim of unimpeded drilling through the challenging Kynovsky clays and drilling horizontal highly deviated holes, PJSC TATNEFT together with Baker Hughes conducted laboratory experiments and field operations to run a casing string into the Devonian deviated (80° and more) well with simultaneous rotation, and subsequent two-stage cementing.

Excessive torque control in directional and extended-reach drilling is a priority issue as the excessive torque easily can cause drill string twist-off. When casing consists of buttress thread pipes there may be a problem of exceeding maximum allowable torque value and subsequent strip failure, as well as the casing string falling, as a result of the threaded connection back-off. Table 1 presents the standards, i.e. maximum allowable make-up torques for casing string. In practice, in some cases when the buttress thread is used it requires an additional torque tolerance ring to be installed.

**Table 1. Allowable (recommended) makeup torque of buttress thread casing connections [6]**.

| Casing diameter (mm) | Allowed make-up torque (kN·m) | Allowed make-up torque during rotation (kN·m) |
|----------------------|-------------------------------|-----------------------------------------------|
| 324*9.0              | 7.5-9.6                       | 7.0                                           |
| 245*7.0              | 5.6-10.2                      | 8.0                                           |
| 178*8.3              | 4.4-7.0                       | 5.0                                           |
| 168*7.3              | 16.0                          | 10.0                                          |

Makeup torque $M_t$, the moment of the torque, occurs while rotating the casing string and is caused by $M_d$ which is necessary to rotate the bit, and $M_{x\tau}$ to overcome the string friction against the walls of the well and the fluid while the string is being rotated. The eventual formula derived is the following:

$$M_t = M_d + M_{x\tau} = n \cdot (D_b \cdot P_b + \frac{(55.8 \cdot 10^{-4} \cdot k_1 \cdot k_2 \cdot k_3 \cdot (1 + 0.44 \cdot cos\beta \cdot (0.9 + 20 \cdot \delta)) \cdot k_4 \cdot q \cdot d_{cs}}{\omega})$$

where: $M_d$ - specific moment (N*m)/(m*kN);
$D_b$ - bit diameter, m;
$P_b$ - weight on bit, kN;
$k_1$ - coefficient for the casing pipe connection;
$k_2$ - coefficient for fluid liquid and anti-vibration grease used;
$k_3$ - coefficient for peculiarities of the borehole walls;
$cos\beta$ - for the angle of the borehole inclination;
$\delta = (D_a - d_{cs})/2$, the clearance between the walls of the well and the casing, m;
$k_4$ - coefficient for the material of the casing;
$q$ - weight of 1 m of the casing, kg/m;
$d_{cs}$ - diameter of the casing pipe/string, m;
$n$ - frequency of the bit rotation, r/c;
$L$ - length of the pipe section, m;
$\omega$ - frequency of casing string rotation, min⁻¹.

Let us consider the example of drilling with a top drive. The casing string is 0.245 m long, drill bit diameter is 0.2953 m, and the target depth is 1500 m. The frequency of the top drive rotation is approximately 100 r/min. The drilling fluid density is 1200 kg/m³.
Even in the theoretical calculations, a value of torque is above the allowable values. This fact leads to the need of developing methods to reduce this value. The magnitude of rolling friction is much less than the sliding friction value, other factors being equal; therefore, rolling is more preferable as the factor to be considered while discussing casing-while-drilling. One of the solutions to reduce the torque is the use of a slidable centralizer, the design of a rigid centralizer with roller balls attached so that it could move freely.

The Department of Drilling Oil and Gas Wells of Almetyevsk State Oil Institute has been conducting a research on methods developed to reduce the coefficient of friction between the drill string and the casing, especially in the wells with horizontal sections [5, 7-18]. The new rigid centralizer consists of housing with end portions in the form of centering collars connected by metal bars, or ribs, (Fig.1) and is secured by bolts to the casing. While moving the metal balls in the centering bands roll along the walls of the well, providing a reliable centering and stabilizing the drill string in the well. The centralizer has a substantially rigid annular body, cylindrical housing, to provide it strength and stability; and a roller ball assembly on its centralizing ends, or collars, is secured in a manner which enables the balls to rotate in all directions.

\[
M_d = 70 \cdot 0.2953 \cdot 100 = 2067.1 \, N \cdot m \\
M_{xr} = 55.8 \cdot 10^{-4} \cdot 1.3 \cdot 0.8 \cdot 2 \cdot (1 + 0.44 \cdot 0.5 \cdot \frac{0.2953 - 0.245}{2}) \cdot 1 \cdot 42.6 \cdot 0.245 \cdot 1.67^{0.5} \\
\cdot 1500^{0.75}/10.46 = 7190 \, N \cdot m \\
M_t = 2067.1 + 7190 = 9257.1 \, N \cdot m = 9.25 \, kN \cdot m
\]

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![Figure 1. A roller ball centralizer.](image)

The assembly is run into the borehole where it will rotate and progressively move with the casing string [5]. The centralizer is able to maintain coaxial placement of a casing string; it plays a significant role in limiting a number of columns of a casing string run to a hole and minimizing the clearances in the hole. Moreover, it assists in reducing mechanical friction and axial resistance both in cased and open holes. In connection with the problem being discussed we would like to add that the Department has been also working on a new design of a casing shoe to facilitate easier running of the casing string (liner) to the bottom of the well, as the device guiding the casing toward the center of the hole and minimizing problems associated with hitting rock ledges or washouts in the wellbore[9].

3. Conclusion

It is a common knowledge that a proper centralizer can improve cementing jobs in horizontal and deviated wells. Drilling experience indicates that poor casing string centralization resulting in channeling is one of the current challenges. Even good cement recipes and good cementing practices
are jeopardized by flow pattern resulting from poor casing centralization. Conventional centralizers for casing centralization have not been successful in highly deviated wells. That is why a new centralizing package has been introduced to be used in the cementing of horizontal and deviated wells.

The authors hope that the innovative tools proposed, i.e. a roller ball centralizer and a special tool design combining a bit and a casing shoe, will contribute to reducing the friction and torque coefficient, provide accurate centralization in vertical or deviated wells, ensure the smooth reaching casing depths and the bottom of the well, and improve casing operations in horizontal boreholes.

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