

Complex well profiles in ERD, ultra-ERD push for extended capabilities in drill pipe performance

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THE ADVANCES in drilling technology required to drill ultra-deep and ultra-extended-reach wells is not reserved to rig capability. Drill pipe performance factors, high-torque connections and hole cleaning also can become limitations in extending the well envelope. Meeting the performance requirements imposed by these deepwater, hostile environments and extreme well profiles is challenging for any drillstring manufacturer.

Deeper and more deviated wells require a drillstring with increased tensile load capability, greater torque capacity and a higher strength-to-weight ratio to overcome high frictional drag forces and improve hydraulic performance, rate of penetration, control of the well trajectory and hole cleaning.

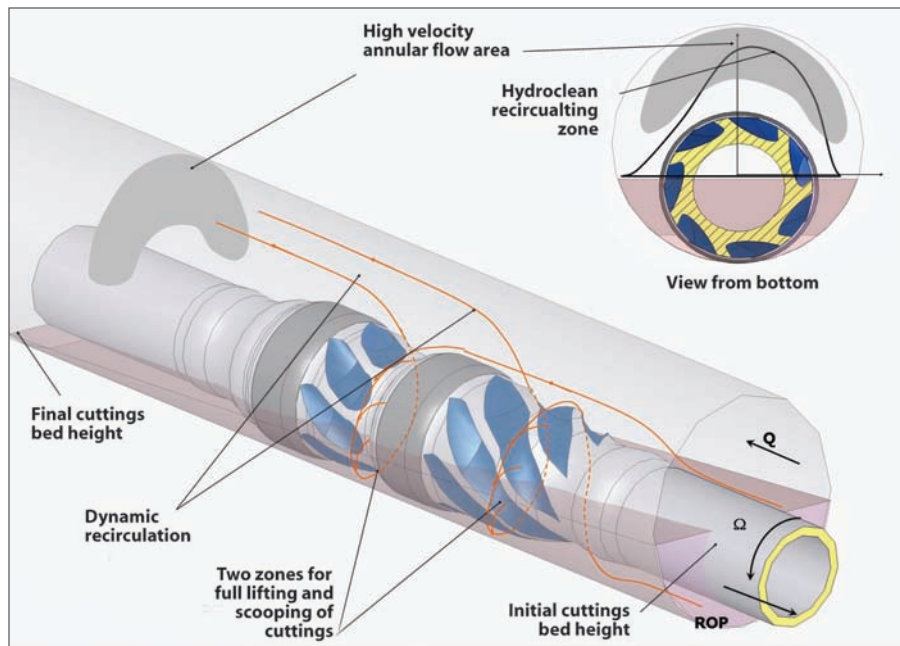
TORSIONAL YIELD STRENGTH

Extended-reach drilling (ERD) has been used successfully both near shore and offshore as much for cost considerations as for its technology application.

For any ER well, one controlling condition is drill pipe performance. Drillstring tensile strength is the first major parameter that determines the capability to drill the well. The strength-to-weight ratio greatly influences the selection of the rig systems, such as circulating pumps and top drives.

For ultra-extended-reach wells (uERD), where the step-out is over 40,000 ft, the need for performance improvement is significantly greater. Manufacturers are being pushed to develop new chemistries, heat-treating capabilities and production improvements for a new generation of higher-strength drill pipe material.

As operators evaluate uERD options, they have been confined to consideration of non-steel drill pipe options for long sections of the well. While these materials have been used for some time in a variety of applications, many drilling engineers are reluctant to pursue complicated and high-value developments with what they perceive as less understood technology.



Hydroclean drill pipe have specially designed grooves or blades. In these bladed sections, the combination of rotational speed, flow rate and the specially designed angles produce mechanical and hydrodynamic effects that significantly improve hole cleaning.



Drillstring tensile strength and torque capacity are major parameters that determine operator ability to drill extended-reach and ultra-extended-reach wells.

These technologies – composite drill pipe, aluminum drill pipe (Al DP) and titanium drill pipe (Ti DP) – all have their pros and cons.

Composite drill pipe offers several advantages over steel drill pipe, including lower weight, higher strength-to-weight ratio, superior corrosion

resistance and enhanced resistance to fatigue. Major disadvantages include hydraulic performance and efficiency. The wall thickness may be twice that of conventional steel drill pipe, resulting in a significantly reduced ID and unacceptable pressure losses through the pipe.

Al DP has many of the advantages of composite pipe... as well as disadvantages. For ERD, Al DP requires a greater wall thickness, again affecting hydraulic performance. It also has a couple of major disadvantages: it is very sensitive to elevated temperatures and costs at least twice as much per ft as steel drill pipe.

Ti DP has significant advantages for uERD wells, including a high strength-to-weight ratio, a high resistance to corrosion and erosion and good fatigue resistance. But like Al DP and composite pipe, Ti DP is exponentially higher in cost than steel drill pipe.

For these reasons, drill pipe manufacturers are developing new ultra-high-strength material that can bridge the gap between existing steel grades and these alternative solutions. Currently for ERD wells, high-strength steels such as 140-ksi and 150-ksi minimum yield strength grades have a relatively modest cost premium over S-135 (135 ksi)

drill pipe. More than 700,000 ft of both grades are in use today. But an increasing demand for enhanced mechanical performance has led to the development of ultra-high-strength steel, with V-165 ksi yield strength, a 22% improvement over S-135.

With operators continuing to push for “high-spec” rig equipment such as large pumps, 7,500-psi circulating systems, larger top drives and 1,000-ton hoisting capacity, the selection of V-165 becomes advantageous in uERD wells. Using this high-strength drill pipe, surface torque loads can be reduced by 15% and pick-up loads by 17%, dramatically improving over-pull capability.

However, the biggest advantage of V-165 is that it allows the lower portion of the drillstring to be thinner-walled than current API specification, resulting in reduced surface torque loads that are more in line with the limits of existing tool joint connection technology.

CONNECTION SOLUTIONS

A second controlling condition for establishing the feasibility of developing ER wells is torque capacity, especially the maximum torque loads of both the top drive and drillstring components. Higher drilling torque was made possible by using top drives instead of rotary tables.

For the drillstring components, solutions include multiple drill pipe sizes – large OD for larger holes and small OD for smaller holes. While different materials have been considered and used in different drillstring sections of ERD wells, a critical element in the torque equation is the tool joint connection and makeup torque.

Torque capacity requirements for the connection are much higher than standard API. Second-generation double-shouldered high-torque connections have been the standard choice for most significant ERD wells for a number of years. Utilization of double-shouldered connections allows full advantage of the torque output of top drives.

These double-shouldered connections provide torque capability 1.5 to 2 times that of API connections and allow change of OD/ID for improved hydraulic performance. Additionally, safety margins are greater as these high-torque connections provide higher torque-to-yield resistance, progressive failure mode if over-torqued and optimized behavior for HPHT drilling conditions.



The Hydroclean technology upset is composed of two distinct zones: the hydro-cleaning zone and the hydro-bearing zone. The negative angle of the blades provides optimum scooping effect while the variable helix angle accelerates the lifted particles and re-circulates them in the upper zone of the hole where fluid velocity is maximum.

However, higher drilling torque requirements have also created the need to increase make-up torque (MUT) and efficiency.

One manufacturer has a high-torque connection that has twice the torque capability of API connections and can be made up in 5-6 turns from stab-in to full make-up, with trip-time up to 16% better than other high-performance connections.

Less turns and easy make-up increases the service life of these connections. Additionally, enhanced clearance between the box counter bore and pin nose limits the stabbing risk. There is reduced wedging risk on the threads, improved pin nose durability and improved drillstring fatigue life because the connection’s patented design includes an elliptical thread root that increase the connection resistance to rotational bending fatigue.

Another manufacturer has developed an ultra high-torque connection that incorporates a double-start thread that also reduces the number of revolutions or turns to assemble the connection by half. Estimates suggest that the connection can save a minimum of 11 hours in trip time for a 30,000-ft well.

These connections can facilitate more challenging wells, provide increased cost savings and reduce risk during the well construction process.

IMPROVED HOLE CLEANING

Cuttings volume for most ER wells is similar to deep vertical wells. ER wells in the 40,000-ft range may generate twice the volume of cuttings, and uER wells in excess of 45,000 ft and beyond may be two to three times that. Thus, hole cleaning becomes an important factor in ERD and uERD wells.

Flow rate is considered to be the main component of hole cleaning as it provides the only physical means downhole capable of achieving a thorough decay and circulation of solid particles. At the same time, flow rates must not degrade the hole, produce equipment wear or create high standpipe pressure.

In many instances, the required levels of flow rate values will not be achievable because of the available rig capability. Further flow rate limitations are restrictions of the maximum equivalent circulating density (ECD) values afforded by the formation. In addition, high flow rates can generate hole enlargement or caving.

Thus, increasing the flow rate, necessary on ERD and uERD wells, can improve hole cleaning within certain limitations, and care must be taken to avoid worsening the well situation.

Rotational speed (RPM) is the second most well-known, and sometimes misunderstood, hole-cleaning component. Although increasing the pipe rotation improves cuttings agitation, rotational speed of the string has a limited effect on cuttings recirculation and cannot achieve a completely clean hole.

The primary advantage of RPM is cuttings agitation, which limits cuttings sedimentation. The lifting effect is created by the upward driving effect of mud flowing lines on the solid particles. Therefore, the efficiency of RPM is more related to cuttings agitation rather than cuttings recirculation.

However, increasing rotational speed increases the risk of drillstring fatigue and dynamic vibration. It also increases the risk of wellbore damage and caving. Additionally, high RPMs can negatively impact ECD values.

Finally, mud rheology plays a significant role for hole cleaning as it impacts cuttings suspension in the flow. The

lubricity of the mud is the main factor helping cuttings suspension. Although an important factor, mud rheology is not an optimization parameter because the mud properties are adapted to the formation and well profile.

Hole-cleaning problems start when operating parameters fail to efficiently circulate cuttings to the surface during either the drilling or tripping phase. When considering the cleaning modes for drilling and tripping, there are three distinct stages that characterize the hole-cleaning process:

- Scooping stage: Solid particles on the low side of the hole must be mechanically lifted in order to decay the cuttings bed and decrease its overall height.
- Recirculation stage: The lifting effect at the scooping stage is not sufficient to ensure cuttings bed erosion. Once lifted, solid particles must be driven all the way up to the high side of the hole, where fluid velocities are at a maximum.
- Transportation stage: Regardless of the energy input exerted on the solid particles during the recirculation stage, after a certain distance, cuttings will eventually resettle to the low side of the hole. This phenomenon is exacerbated in ER wells. The transportation stage is designed to establish a “conveyor belt” that will continuously transport cuttings from downhole to the surface.

Therefore, an efficient hole-cleaning process is the combination of a complete bed erosion action with a “cuttings conveyor belt” mechanism that will transport the maximum amount of solid particles to the surface.

In order to optimize hole cleaning, a complete hole-cleaning system must be in place. However, even with a fully optimized system, it may still be impossible to clean the hole sufficiently to achieve the desired drilling performance. A “mechanical” boost of the system is required.

Hydroclean drill pipe and heavy-weight drill pipe is a new-generation hole-cleaning and torque management tool that provides that “mechanical” boost. Integrally machined on full-length joints, Hydroclean upsets have specially designed grooves or blades. In these bladed sections, the combination of rotational speed, flow rate and the specially designed angles produce a num-



Fewer turns and easy make-up increases the service life of connections. Enhanced clearance between the box counter bore and pin nose also limits the stabbing risk.

ber of mechanical and hydrodynamic effects that significantly improve hole cleaning.

The Hydroclean technology was developed to achieve improved cuttings scooping and re-circulation by a mechanical means. The Hydroclean upset is composed of two distinct zones: the hydro-cleaning zone and the hydro-bearing zone. The negative angle of the blades provides optimum scooping effect while the variable helix angle accelerates the lifted particles and re-circulates them in the upper zone of the hole where fluid velocity is maximum.

The hydro-bearing zone of the profile protects the wellbore from the blades and provides optimized sliding properties because of the low friction profile of the hardbanding.

The Hydroclean transportation effect is ensured by creating a so-called “cuttings conveyor belt” as its joints are integrated into the drillstring in order to place its profiles in the critical sections of the hole. As the tendency of the solid particles is to redeposit after being re-circulated, its upset spacing (from one joint every two or three stands) is optimized by taking into account the operating parameters, which will impact the transportation of cuttings in the mud flow.

Other benefits of this pipe profile include torque and drag reduction, improved sliding behavior of the drillstring, better weight on bit transmission, wellbore protection, stuck pipe prevention and casing and equipment wear prevention.

Hydroclean solutions and hole-cleaning management systems have been used on more than 400 applications worldwide. Observations from drilling engineers and rig crews include have included:

- Cuttings appearing at the surface in a reduced amount of bottoms up.
- Increased size of cuttings over the shakers in excess of 14% larger.
- Reduced ECD and T&D as a result of a cleaner hole.
- Reduced number of wiper trips to clean up the hole.
- Reduction in back-reaming.

IN CONCLUSION

With all the challenges of developing ERD and uERD wells, major strides have been made in drillstring performance properties and components to overcome torsion, torque and hole-cleaning problems. ♪