[EXTREME]

TRADING IN THE TRADE-OFF

ARON DEEN AND BEN PHILLIPS, ULTERRA, USA, EXPLAIN HOW NEW DRILL BIT TECHNOLOGY DESIGNED FOR EXTREME DURABILITY AND PERFORMANCE IS ALLOWING OPERATORS TO INCREASE ROP WITHOUT SACRIFICING BIT LIFE.

In the world of drill bit technology, a guiding principle held that there was a trade-off between durability and performance. Either the bit could be durable and drill for a longer amount of time, but not be the fastest, or the bit could drill the fastest, but not be durable.

This principle was more applicable to roller cones, which crushed rock with weight alone. As the rock became harder, the inserts were more likely to fail before the rock, requiring smaller, blunter, tougher inserts that slowed down the rate of penetration (ROP). Too often, the same thought process has been applied to PDC bits – 'if the bit isn't making it to TD, add more blades and cutters' – which slows down the PDC.

If this approach assumes the cutters are the weakest link, even the addition of reengineered cutters may not ensure durability and performance because there is a new drilling system dynamic in play. Operators are applying substantially higher torque and weight on bit (WOB) to decrease drilling days and the cost per foot. The extreme force is putting extra strain on the drilling system, including PDC bits that can experience catastrophic failure if not engineered holistically for this new situation.

In order to meet this challenge, Ulterra launched a rigorous, 18 month research and development initiative to develop a solution. The Ulterra® XP™ PDC bit – synonymous with tougher drilling, faster ROP and reduced trips to reach TD in less time with excellent hole quality – succeeds in durability and performance (Figure 1).

RECORDING HIGHER TORQUE AND WOB

As recently as three years ago, a positive displacement motor averaged a maximum torque from 4000 - 6500 ft/lb. Today, in the Permian Basin, operators are asking for a maximum torque up to five times greater at 20 000 ft/lb.

Ulterra regularly receives enquiries from consultants and drilling engineers who say that they are already running over the specified torque and weight maximum, but want to know if they can go higher because they know the bits can handle the additional energy.

This trend is not isolated to the Permian. In the Mid-Continent's South Central Oklahoma Oil Province (SCOOP) and Sooner Trend Anadarko Basin Canadian and Kingfisher (STACK), WOB has increased to 100 000 lb or more than three to six times the typical 15 000 - 30 000 lb.

With such punishing power, operators are paying for failing motors, cracking transmissions and blown-out power sections. Other catastrophic failures, such as broken blades on PDC bits, have occurred at a greater rate as old-school bit designs are subjected to new-age power. The demand to get to TD rapidly is putting a strain on the drillstring and the drill bit, as greater ROP is necessary to get through transition zones in the least number of days to lower the cost per foot drilled.

UNDERSTANDING THE HIGHER FORCES

Because operators agree this new dynamic is not changing anytime soon, the Ulterra R&D team set a high-level, urgent priority early in 2016. The goal was to engineer a new PDC for unforgiving drilling conditions. This project was not about finding the weakest link. Everything was open for review and rework. A new PDC bit design, which would ensure this part of the drillstring is not an operator's limiting factor, was underway.

The R&D team's holistic approach looked at the bit from the connection to the cutters, which would have to be more robust, resilient, and reliable. The cutters had to absorb and survive the increased drilling system energy. The cutting structure would be included. But, none of that would matter if the body and its blades could not consistently withstand and convey that energy to the cutting structure. The R&D team also had to examine the material science, in addition to the manufacturing and repair process.

In other words, the team had to ensure every link in the PDC drill bit design, manufacturing and repair chain was strong. One weak link, and the project would be sent back to the drawing board.

Each of the improvements were independently tested and retested in real world drilling environments. What was learnt through this process made the XP product line possible and, as an important added bonus, raised the bar of reliability on the other bits now designed and built by the company.

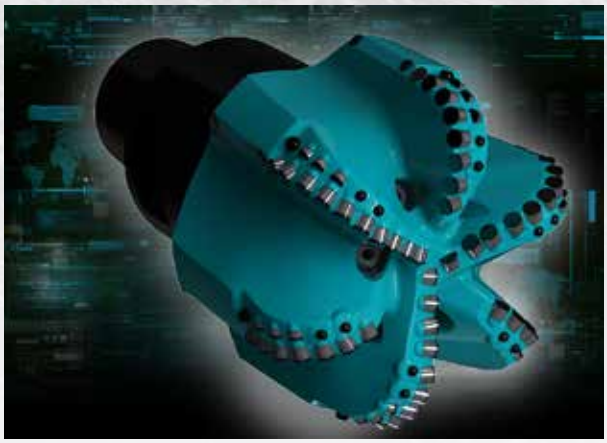

Figure 1. *The XP PDC bit is designed to provide enhanced durability and performance and enable operators to drill with extreme power for extreme penetration rate with fewer trips.*

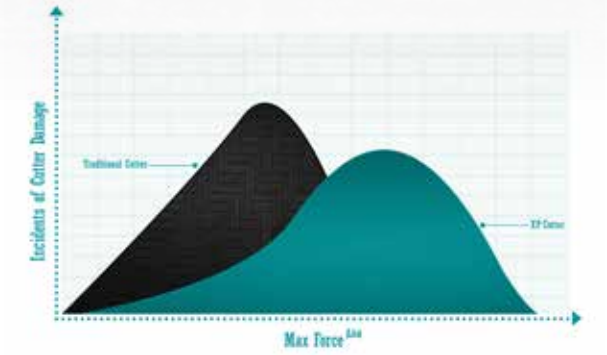

Figure 2. *Results from tests in real world and lab environments show that XP cutters can take greater force with less cutter damage compared to previous generations.*

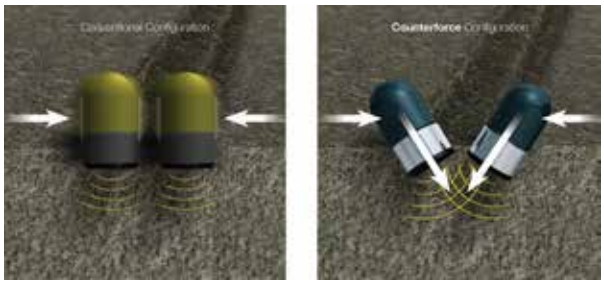

Figure 3. *CounterForce® technology redirects lateral forces from the bottomhole assembly into the formation, failing and removing the rock more efficiently.*

ENGINEERING DURABILITY AND PERFORMANCE

In this holistic project, the R&D team looked at four element groups: the cutters; the cutting structure; the bit body; and the material science, manufacturing and repair.

First, the new cutters. PDC cutters fail the rock to make the hole and drill the well. The Ulterra team analysed the location and purpose of each cutter. The team worked iteratively with all of the major PDC cutter manufacturers for this XP product line, resulting in cutters specifically tailored to withstand the most extreme downhole forces.

In these applications, cutters fail in some unique ways. The company iterated through dozens of variations of cutter improvements to find the optimal solution for high energy drilling (Figure 2).

Second, the new cutting structure. Considering how the entire bit engages with the wellbore, the R&D team gave special consideration to a commonly overlooked detail: the gauge cutting structure and pad. Under extreme loading, a sharp edge on the gauge can clip the borehole wall, which can aggravate the stem into whirl and stick-slip. These excited states of vibration are the leading causes of bit and tool damage. A new tapered rake angle added to the entire leading edge of the gauge structure prevents whirl and stick-slip.

Secondary cutting elements, including depth-of-cut and load limiters, were also fortified with supporting geometry. R&D also decided to include the company's CounterForce™ technology, which redirects lateral impact from the bottomhole assembly into the formation, failing and removing the rock more efficiently (Figure 3). The patented cutter angle arrangement produces a reliable bit that slices the formation and remains sharper longer with a higher penetration rate while reducing trips.

Third, the new body, including the blades and the blades' geometry, which are some of the most critical characteristics of a PDC bit because the blades hold the cutters in place. The team researched a new PDC body paradigm using finite element analysis. Now, the six blades grow out of the body instead of the typical way blades have been designed onto the body separately.

This principle also led to anchoring the secondary blades to the body centre with every single blade is connected to the others, effectively doubling the blade strength while enhancing the cutting structure (Figure 4). Making educated trade-offs in relocating strong body geometry and void volumes for fluid led to a more aggressive, tapered junk slot that improves cutting evacuation efficiency.

Figure 4. *The blades grow out of the bit body, a new design paradigm that doubles the blade strength while enhancing the cutting structure.*

Fourth, the material science, manufacturing, and repair. Materials are all too easily overlooked, but can make a world of difference. Toughness, hardness and strength are all important, and a whole new series of materials was literally put under the microscope to achieve an optimal balance. Since the US land drilling industry is a PDC bit rental market, a critical reliability factor is determined by how these bits are treated through multiple repairs. Ulterra, which includes servicing PDC bits in the scope of its API Q1 certified quality management system, has taken extra steps to ensure every bit meets the same high bar for quality.

"While these new bits are visibly different not every improvement can be seen," said Beau St. Pierre who led much of the R&D effort. "We did a lot of research and testing with materials, hot-work processes, and threaded connections that certainly improve the bit."

PROVING UP THE DESIGN

Operators are succeeding in difficult applications in the Delaware Basin, for example, with this new PDC. A Delaware Basin vertical interval is one of the harshest vertical intervals in the Permian Basin, and one of the toughest to drill in the US. Hard rock with ratty transitions tends to break almost everything that goes into the hole. The typical goal of every operator working in this interval, regardless of hole size, target formation and tools, is to make as much footage as fast as possible. Operators are running harder and harder on downhole tools and equipment to find the breaking point. One operator, working in the northern part of the basin and making a bigger push than most others, chose the XP 8 ¾ in. PDC to achieve its goals. The operator achieved company record-setting footage and ROP by drilling more than 9400 ft in 61 hr at an average ROP of 137 ft/hr.

The Midland Basin's 12 ¼ in. interval is one of the toughest. Operators' PDC selection requirements vary greatly: some need only to drill a couple of thousand feet at a fast ROP while others need a PDC to withstand west Texas transition zones for nearly 7000 ft. One operator in the southern Midland Basin decided to make an interval as fast as possible by challenging the upper limits of weight on bit. The operator, who chose the XP 12 ¼ in. PDC, beat a previous company record set with another Ulterra PDC bit by drilling 7315 ft in 35 hr for an ROP of 209 ft/hr. The operator, who has gone on to set multiple company ROP records with this new PDC, continues to push the limits past anything peers are doing. This line of PDCs is now the operator's go-to choice to meet these demands.

SUMMARY

The XP PDC bit is an effective answer to new drilling programmes with significantly higher torque and WOB, one of the most important oilfield trends. The R&D team's holistic approach to inventing this technology has produced a solution that disperses these increased forces into the formation to prevent catastrophic bit failure. The technology's durability and performance make it suitable for the roughest drilling applications, including the harsh rock of the Permian Basin. [X]


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