

*DRILLING
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DC DRILL BITS

DC Drill Bits
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Preface

By Mike Killalea, IADC Group Vice President/Publisher

Drill bits are the business end of a drilling rig and the gateway to subsurface resources. The introduction of rollercone bits in 1909 by Howard Hughes Sr. represented an enormous step change in drilling technology. With rollercone bits, rotary rigs came into their own. Previously, drillers used a drag-type, "fishtail" bit that scraped and sheared the bottom of the well. This was a clear improvement over percussion drilling technique that was standard for the fading technology of cable-tool rigs. But the fishtail bits were not durable enough to penetrate hard, abrasive formations and were limited to soft formations. With roller cones, rotary rigs could finally economically and efficiently drill through those tougher rocks.

In the decades following the Hughes bit, rollercone bit technology made enormous strides. The now-standard third cone was added. Thanks to improved welding techniques, tungsten-carbide hardfacing was added, increasing durability. The later enhancement of pressing tungsten-carbide inserts into predrilled holes in the bit body further toughened roller cones. Nozzles were incorporated into the bits to improve hole cleaning. Seals and O-rings were introduced.

At the same time, another revolution in bit tech was under way. Work to cut rock with diamonds began in the 1940s, resulting in the 1976 commercial introduction of polycrystalline diamond compact (PDC) bits. By 1982, the first cylindrical PDC cutters were introduced, with synthetic diamond cutters bonded to the bit body. Today, PDC bits account for the vast majority of worldwide footage, as an article in this book discusses.

Advances in bit technology continue. This anthology brings together some of the best of recent drill bit technology published in *Drilling Contractor*, the official magazine of IADC.

The 18 articles within cover a wide range of technical advances in modern drill bits, as well as a definitive history of PDC bits. These articles represent a strong sampling of the continuing work to enhance drilling efficiency and economics. We gratefully acknowledge and thank the authors who wrote articles for DC, for this anthology and for keeping the industry turning to the right.

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DRILLING CONTRACTOR ANTHOLOGY SERIES

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BETTER AND BETTER, BIT BY BIT

New drill bits utilize unique cutting structures, cutter element shapes, advanced modeling software to increase ROP, control, durability

By Linda Hsieh, Managing Editor, and Alex Endress, Editorial Coordinator

The drill bits market is an ultra-competitive one. Operators are constantly on the lookout for newer, more robust bits that can drill faster or farther through increasingly aggressive curves and longer laterals. At the same time, they demand durability and control through a wide range of formations. To help increase ROP, bit manufacturers are pushing ahead on more advanced algorithms for better modeling – knowing exactly how a bit will react in a certain formation and how to customize a bit for a specific application. Bit companies also continue to reexamine everything from cutter placement to cutter element shapes to protective cutter caps. Each company demonstrates a different approach on the path to improvement, but it's clear that their ultimate goal is the same.

"At the end of the day, our goal is to develop innovative products that allow us to drill holes in the ground more efficiently and to save our customers money so that they will drill more holes in the ground," Tim Beaton, Vice President of Engineering and Manufacturing for Shear Bits, said. In this article, DC gets updates on drill bit technologies from Tercel Oilfield Products, Baker Hughes, Shear Bits, Halliburton, Schlumberger and Varel International.

From core generation to ROP optimization

When Tercel launched the first generation of the MicroCORE PDC drill bit several years ago, the company was looking to provide a bit that could produce small core samples while drilling. At the time, the development of this bit was largely driven by the requirement for these "microcores" to be sufficiently sized to facilitate geological evaluation. Over time, however, the company realized that the bit's unique cutting structure – initially optimized for core generation – could be enhanced to improve ROP instead. Late last year, after some redesign work around the bit profile, PDC cutters and hydraulics, as well as optimization of the diameter and depth of the

Drill bits highlights

- Manufacturers rethink cutter placement on PDC, hybrid bits to direct more force to formation without compromising control.
- Improved modeling capabilities provide better understanding of how a specific bit will react in a specific formation, allowing for pre-deployment customization and fit-for-purpose bits.
- Unique cutter protection measures are being developed to help prolong bit life in multiple formation types.

core chamber and the "microcore" shearing process, the company launched an updated version of the bit.

It applies PDC cutters to the outer diameter of the bit face and eliminates cutters in the center of the bit – instead implementing a cylindrical chamber through the middle of the bit for core generation. An additional shearing cutter in the back of the coring chamber cuts off the core of formation collected, which is then released from the bit and circulated to the surface up the annulus for evaluation, if desired.

"On a traditional bit, a large portion of the drilling energy is consumed in the center of the bit where the cutters are not moving very far around the radius, versus the outside of the bit, where those cutters are moving very quickly," Mark Freeman, Tercel VP of Drill Bits and Drilling Enhancement, said. "By removing those cutters in the center of the bit, we are redistributing that energy to the part of the cutting structure that is doing the most work."



The Tercel MicroCORE drill bit applies PDC cutters to the outer diameter of the bit and eliminates cutters in the center of the bit. This placement helps to focus energy on faster-moving outer PDC cutters. Originally designed to produce “microcores” through the center of the bit for geological evaluation, the bit was recently optimized to focus on increasing ROP. The bit has been used in places such as the Eagle Ford, Bakken, the Tunu Field in Indonesia and the Southern North Sea.

In summer 2014, this new bit was used in three horizontal wells in the Eagle Ford in South Texas, next to five similar wells using non-core cutting PDC bits. The operator was specifically looking for ROP gains in the 8 3/4-in. production interval. “They were having issues with ROP while drilling their curve and their lateral,” Mr Freeman said. He added that the operator was kicking off the build sections at around 8,500-ft at 10-14°/100 ft, then continuing to drill 7,000-ft laterals without tripping for a BHA or bit change. TDs for all these wells were approximately 16,500 ft.

The MicroCORE achieved 92 ft/hr average ROP, while the other PDC bits in offset wells – also drilling the curve and lateral sections – achieved 72 ft/hr. “In most cases, the operator will make the run with one bit

in the Eagle Ford. It’s just a question of how quickly they can do it,” Mr Freeman said. Besides the Eagle Ford, the new version of this bit has also been run extensively in the Bakken in North Dakota, the Tunu field in Indonesia and the Southern North Sea in the UK.

Adding speed to control

Last year, Baker Hughes commercially launched its second-generation hybrid bit, Kymera FSR, which combines features of a PDC and roller cone bit. While the first-generation model, launched Q4 2011, worked well in hard and interbedded formations, the company saw room for improvement in softer formations and in carbonates, Baker Hughes Product Manager Alan Holliday said.



Top: Tercel's MicroCORE PDC drill bit produces "microcore" samples (center) for improved geological evaluation, as well as larger cuttings (right). Bottom: Baker Hughes' Kymera FSR directional hybrid bit combines a more aggressive PDC cutting structure with roller cone features to increase ROP while keeping control.

To reach these markets and improve the overall efficiency of the bit, the company began seeking ways to make the bit more aggressive while still maintaining its low torque response. To address this, Baker Hughes developed an optimized roller cone and PDC cutting structure. This new structure allows the bit to drill with lower weight on bit (WOB) requirements while achieving higher overall ROPs compared with the first-generation model. "We found that we were able to improve the efficiency, yet maintain the smooth drilling that directional drillers came to appreciate from the first generation," Mr Holliday said. He added

that the optimized design improved performance in carbonates by 50% to 100%.

In an Eagle Ford project in Q4 2014, an operator chose the second-generation hybrid bit to drill curves in three separate wells in the Austin Chalk and Anacacho formations. The PDC bits that were being used were creating high torque fluctuations, sending the BHA off its planned trajectory and requiring at least two bits to get through the curve. In addition, the high torque fluctuation forced the operator to reduce WOB, limiting ROP.

The new bit was selected to drill three curves that averaged 789 ft each, and average total depth for the three wells was 12,600 ft. The first well was drilled in 22 hrs at an average ROP of 36 ft/hr. The second bit finished the section in 17 hrs, averaging 46 ft/hr ROP. The third run averaged 41 ft/hr.

Two offset wells each required multiple bits to drill the curve, with one requiring three bits over 35 hrs, for an average ROP of 23.7 ft/hr. The other well required two PDC bits over 27.5 hrs for an average ROP of 32.2 ft/hr.

Each Kymera bit was pulled out in "green" condition, according to Baker Hughes. The operator reduced cost-per-foot in each curve by at least 36% and saved a total of \$503,122 on all three runs combined, Baker Hughes stated.

Two-step cutting structure

Halliburton's line of GeoTech fixed cutter PDC bits, launched in February, is geared toward difficult-to-drill applications, such as hard or abrasive formations or formations that transition back and forth between hard and soft rock. It features a two-step cutter layout position that, compared with a traditional cutting structure, takes some of the cutting structure off the profile of the bit face so that some cutters are cutting more than others, according to Halliburton. "You may have a very soft section where you don't need as much cutting structure... and then you may get into a harder or more abrasive formation later where you need that extra diamond," Halliburton Product Manager Brad Dunbar said. "We're trying to optimize having a very light structure in one part and a much heavier-set cutting structure in another." Operating parameters can be adjusted to help the bit engage the second cutting structure where necessary, he added.

Advanced materials have been incorporated into the bit, including new matrix/binder materials and more abrasion- and impact-resistant diamond cutters with increased thermal mechanical integrity. However, Mr Dunbar emphasized that while these materials make

the bit more robust, they will not produce results if they're put to the field without fully understanding how they're going to be used. That's why advanced simulation plays a key role in the performance of these new bits.

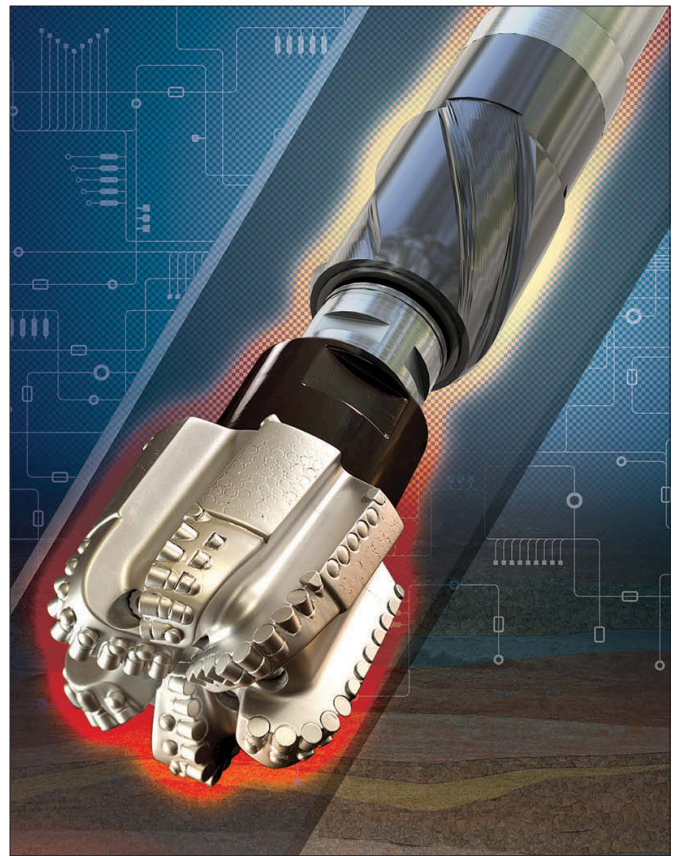
Late last year, Halliburton introduced a new version of its IBitS 3D design software, featuring updated algorithms and models. Working in conjunction with Halliburton's rock interaction model, these tools can help to more realistically simulate formations and how the bit will interact with the formation. "Being able to simulate better helps you to change the cutting structure of the bit or change the material in the bit to accomplish what you need in order to hit the ROP or footage that the customer is looking for," Mr Dunbar said. If an operator wants to drill faster, for example, the software can tell you where to place the right amount of cutting structure in the right place on the bit in order to achieve that.

Early this year in the North Sea, the GeoTech bit was used to drill the 12 ¼-in. section of an offshore well through seven distinct formations. The GeoTech GTD65D bit was tripped in to drill the entire 8,254-ft interval. The bit achieved an average ROP of 93 ft/hr, compared with an average ROP of 74 ft/hr for three offset wells, saving at least 11 hours of drilling time. When pulled, the bit had a dull grade of 1-1-BT – much less damage than the offset bits, according to Halliburton.

Concentrating on efficiency

Compared with conventional cylindrical PDC cutters, the Stinger diamond element used on the StingBlade Conical Diamond Element Bit is a conical-shaped cutting element. This shape allows the cutter to apply a higher concentrated point load on the formation to fracture high compressive strength formations more efficiently with a combination of plowing and shearing mechanism. Coupled with the unique geometry of the Stinger elements is a thicker diamond layer, which provides improvements in impact strength, enabling these bits to drill further and faster.

Allen White, Product Champion at Smith Bits, a Schlumberger company, explained that after analyzing more than 1,000 runs accrued so far by the StingBlade bits, the company has seen a 55% improvement in footage drilled compared with the baselines, as well as a 30% increase in ROP. "With previous technologies, there has always been trade-off in durability and bit speed... so the ability to create longer footage runs and higher overall ROPs is quite ground-breaking," Mr White said.



Halliburton's GeoTech fixed cutter PDC bit is geared toward difficult-to-drill applications, such as hard or abrasive formations or formations that transition between hard and soft rock. Bottom right: The unique cutter geometry found on Schlumberger's StingBlade conical diamond element bits provides the ultra-high concentrated force necessary to efficiently fracture high-compressive strength rock for improved footage, ROP and build rates.

He also cited better toolface angle control from having a more concentrated point load, which applies WOB more efficiently and allows energy to transfer more effectively from the cutters into the formation. "When a hard stringer or interbedded formation is encountered while steering with a conventional PDC bit, the result is typically high fluctuations in torque and toolface angle, which can result in lower build rates and more time to achieve directional objectives. Due to the conical shape of Stinger elements on StingBlade bits, the magnitude of the torque and toolface angle fluctuations are reduced, allowing directional drillers to stay on target and finish curve sections faster," Mr White said.

"We've also found the ability to reduce bit and BHA shock and vibrations for overall improved drilling efficiency and for prolonging BHA tool life," he continued.

He explained that the conical shape of the element has a force profile when drilling that is much more



Top: Shear Bits' Pexus bit, a PDC and carbide hybrid bit, uses carbide elements to shear hard formation to protect PDC cutters from damage. Bottom: The Pexus bit has been used extensively in Western Canada to drill glacial till, comprised of a hard top layer of boulders and gravel, and a soft bottom layer of sand and shales.

symmetric about its centerline than a cylindrical PDC cutter. Therefore, the resultant lateral forces of each Stinger element are lower than a PDC cutter.

"If you take all of the cutting elements across a bit cutting structure, the more Stinger elements on the bit, the easier the bit has shown to be balanced in our IDEAS software, and we've seen similar results

in the field." The IDEAS design platform is used at Schlumberger to help engineers model the entire drilling system, from surface to the drill bit, including bit-rock interaction. This allows engineers to evaluate bit performance in a virtual environment and optimize placement of the diamond elements across the cutting structure.

In a field test done in Q2 2014 at Schlumberger's testing facility in Cameron, Texas, a StingBlade bit and a conventional PDC bit were run in adjacent boreholes less than 50 ft apart, drilling 800 ft using the same rig, BHA and operating parameters. The formation consisted of interbedded limestone, sandstone and shale with compressive strengths exceeding 15,000 psi in some portions, Mr White said.

A drilling dynamics logging device placed at the bits showed that the StingBlade produced 53% fewer lateral vibrations and 37% fewer axial vibrations compared with the conventional PDC bit.

StingBlade bits have seen success in 27 countries so far, according to Schlumberger. In one project offshore Australia from Q3 2014, an operator chose the bit to drill a 12 ¼-in. vertical section in the Browse basin through the challenging Dampier, Heywood, Baudin Marl and Wollaston formations. Made up of high compressive strength interbedded hard limestones and chert, these formations in the Browse Basin are known to produce heavy damage to conventional PDC bits.

To address bit durability and ROP, two 12 ¼-in. StingBlade bits were used. The first drilled 1,516 m at 11 m/hr, equaling to 97% more footage than the best run in the same section of the offset well, according to Schlumberger. The second bit drilled the remaining section to TD at an average ROP of 16 m/hr, adding up to a total of five days of drilling time saved in the section, the company stated.

Drilling through multiple layers

Choosing a drill bit can be difficult when dealing with an interval that has a top layer of boulders and gravel and a bottom layer of softer sands and shales. The top layer can wreak havoc on traditional PDC bits, and using a roller cone bit in the bottom layer would be inefficient. "A lot of PDC bits can't drill that kind of rock – the gravel and boulders – so a conventional PDC bit won't survive the surface interval. It will get damaged very quickly trying to drill these very hard rocks," Mr Beaton said.

To address this challenge, Shear Bits launched the Pexus hybrid bit last year. The bit's primary cutting structure is made up of rotating carbide elements,