THE EVOLUTION OF HYBRIDS

ALEX WONG, SHEAR BITS, CANADA

HIGHLIGHTS HOW NEW DRILL BIT TECHNOLOGY IS IMPROVING WELLBORE ECONOMICS.

Although the recent slowdown in global drilling activity and the persistence of reduced oil prices present a tough economic challenge for many oilfield service companies, the present condition of the drilling industry also paves the way for innovation and new ways to improve wellbore economics. More specifically, in the world of drill bits, there are currently vast opportunities for small, focused development teams to turn their attention toward the progression of new technologies, especially as conventional drill bit designs continue to approach their technical limits in terms of performance and durability.

The vast majority of wells around the world are still drilled by traditional PDC and rollercone bits, both of which have unique sets of benefits and drawbacks. The shearing mechanism of PDC bits enables increased rate of penetration (ROP) capability and aggressive drilling behaviour, but can often produce undesirable torque response. In terms of durability, some applications still cannot be feasibly drilled by PDC bits, due in part to the limitations of even the industry's best PDC cutters to resist abrasive, thermal and impact damage in a conventional fixed-cutter layout. Rollercone bits and some hybrid designs continue to excel in certain situations – for instance, when excellent toolface control or high impact resistance is desired – but often lack in ROP potential and are restricted in operating hours by seal and bearing life.

To address the limitations of conventional drill bits, SHEAR BITS introduced Pexus™ Hybrid Drill Bit technology to the industry in mid-2013, and since then, has evolved the technology through a philosophy of continuous improvement. Each run with these bits brings valuable new information to the development team, which communicates closely with operators to find opportunities to increase performance and expand the technology into a wider range of applications. In a few short years, these bits have performed hundreds of runs, totalling over 1 million ft drilled.

Advantages of the technology

Pexus Hybrid Bits employ a layout comprising a set of primary, leading gouging inserts, and a secondary PDC shearing cutting structure[1] (Figure 1). The gouging elements are offered as either rotating or fixed components in either carbide or diamond, and other custom configurations are available to suit a wide variety of applications. This hybrid cutting structure provides performance advantages in three key ways:

- Uses two cutting structures to fail the formation, with the gouging elements in a leading position to fracture the rock initially. Consequently, the individual loading on each trailing PDC cutter is lessened, enabling them to maintain ROP and stay sharper in longer runs.
- Gouging inserts in a leading position protect the secondary PDC cutting structure by dislodging clasts from the formation such as large debris (gravel and boulders), or coarse grained conglomerates (large pyrite and chert fragments). These particles can be carried away through fluid pathways before they are able to damage the PDC cutters.
- Fine adjustment of the relative position between the gouging and shearing elements enables the bit to control the amount that each cutting structure interacts with the formation. This has repeatedly proven to provide a far smoother torque response and greater directional control over conventional PDC bits.

Stages of evolution

To date, the technology has undergone three major 'generations' of development, each of which targeted a different range of applications where conventional drill bit designs fell short. Efforts are underway to both improve on current designs and bring completely new ideas to the table.

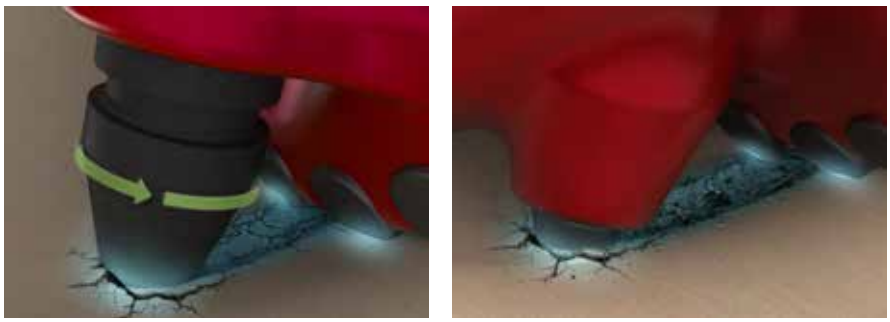

Figure 1. *Pexus hybrid gouging/shearing cutting mechanism using either rotating (left) or fixed (right) inserts.*

First generation

Generation 1 Pexus designs were born out of a need for a more effective drilling solution in formation types where PDC bits were easily and quickly damaged – this includes gravel, boulders, chert, and pyrite, which are normally drilled by rollercone bits at relatively low ROPs. Test runs in these rock types have also been performed in the past using mining bits, but were met with limited success (mining bits contain gouging inserts as the only cutting structure). Although these

Figure 2. *Generation 1 (left), Generation 2 (centre), and Generation 3 (right) Pexus hybrid designs.*

test runs occasionally showed promising ROP potential, they typically became damaged beyond repair in intervals as short as 500 ft. Such a lack of durability can be attributed to the inability of gouging inserts alone to withstand harder and more consolidated formations.

The Generation 1 design (Figure 2) features densely spaced gouging inserts positioned well above the PDC cutting structure – this results in very smooth drilling behaviour and excellent durability. Even the first prototype bit produced positive field results on its initial runs, thereby proving the inherent performance advantages of the hybrid technology. However, due to the excellent condition of the majority of the dulls, the development team concluded that more ROP could be gained by making a few key design changes.

Second generation

The Generation 2 design (Figure 2) features more widely spaced gouging inserts positioned closer to the PDC cutting structure. This enables the PDC cutters to engage more actively in the formation, to significantly boost ROP while retaining the durability and control benefits of the hybrid technology. Wider insert spacing also allows for increased face volume and flexibility in hydraulic layouts, enabling the bits to clean and cool both cutting structures effectively at higher ROP.

One of the most consistently successful applications for Generation 2 designs is in Western Canada, drilling 2000 ft surface intervals in a single run that would otherwise require at least one rollercone and one PDC bit. Operators in these applications save many hours by eliminating a trip while even occasionally matching the ROP of a PDC bit. The excellent steerability of these designs has also been demonstrated by numerous other runs on directional assemblies in bit sizes ranging from 6 ¼ in. to 24 in., many of which replaced rollercone bits and successfully met demanding directional requirements.[2]

Third generation

The company identified even more opportunity for Pexus technology by directly targeting the conventional PDC market. Generation 3 designs (Figure 2) were developed to match or exceed the ROP capability of PDC bits in these applications, while using the Pexus cutting structure to improve torque response and protect the PDC cutters from damage. They generally contain fewer blades than conventional PDC bits – for example, in one 12 ¼ in. diameter Western Canadian application that typically uses 616 (six blades, 16 mm cutters) or 519 type PDC bits, more aggressive 419 type Pexus designs have achieved continued success in terms of both ROP and durability.[3]

Generation 3 designs also feature a significant change in hydraulic layout that aims to improve cooling in thermally demanding environments, and provide superior cleaning in high ROP applications. Computational fluid dynamics (CFD) analyses were performed to illustrate the positive effects of having dedicated flow paths directly in front of each cutting

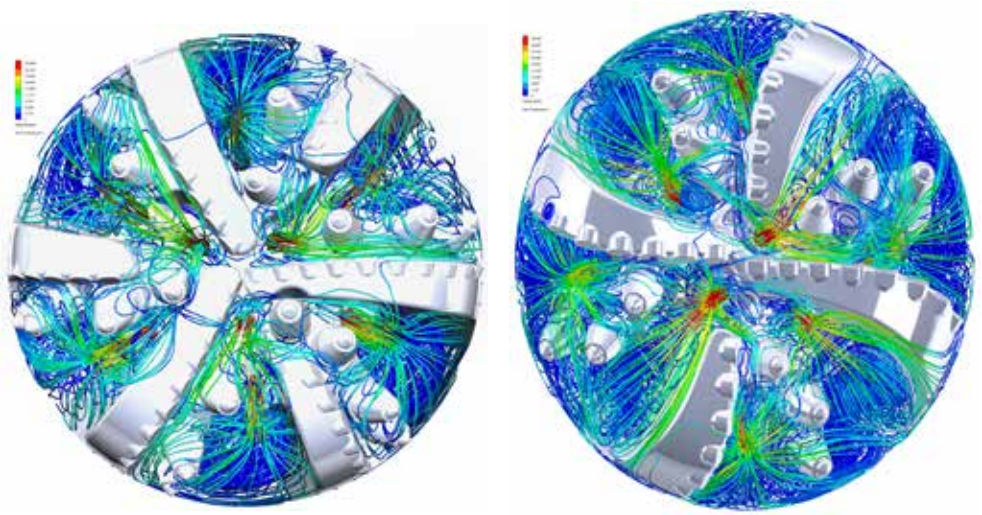

Figure 3. *CFD comparison between Generation 2 (left) and 3 (right) Pexus hybrid designs.*

Figure 4. *From left to right: a 12 ¼ in. hybrid bit, a 8 ¾ in. hybrid bit, and a 6 ¼ in. hybrid directional bit.*

structure (Figure 3). Additionally, to meet the demands of more main hole applications (typically below 8 ¾ in. diameter), many of these designs are built using non-rotating diamond gouging inserts that maximise wear resistance in long and challenging intervals.

Case studies

An operator in Western Canada was attempting to drill an 8 ¾ in. diameter interval, reaming a 95 ft long section in a predominantly hard limestone formation of roughly 20 ksi compressive strength, followed by a 185 ft interval in a predominantly dolomite formation of comparable strength. Although short, this interval is very challenging mainly due to the lithology of both formations – reaming is difficult with conventional PDC bits, which frequently produce erratic torque response, poor hole condition and excessive damage on the gauge area of the bit in similar wells. Instead, 547 or 617 type carbide insert rollercone bits are generally used, but usually only ream at a 6 - 10 ft/hr average ROP and are subsequently tripped out for a PDC bit in the lower section. Using a Generation 3 Pexus hybrid design (Figure 4) enabled the operator to ream at approximately twice the ROP of a typical rollercone, saving over 10 hours of operating time, as well as eliminating a trip by drilling the entire section in a single run.

The dull condition (Figure 5) showed minimal component damage in the cone and nose of the bit, largely due to the added protection provided by the hybrid cutting structure. The reaming portion of the run caused moderate to heavy breakage of the gouging inserts and some PDC cutters on the outer shoulder and gage; thus, it was concluded that future designs for main hole applications could benefit from additional diamond volume and protection in these areas.

Using the lessons learned from the 8 ¾ in. run, a Generation 3 Pexus design (Figure 4) was provided for a different operator in Western Canada, drilling a 6 ¼ in. diameter, 1330 ft long build interval through two formation types both consisting primarily of siltstones with interbedded shales. In order maximise durability in an application with high impact, abrasion and thermal demands, the design featured twice as many blades of PDC cutters on the outer shoulder and gauge compared to the 8 ¾ in. bit.

The operator commented that the bit provided very consistent toolface control, even when run with extremely high weight on bit (up to 40 000 lb) while sliding and when transitioning from one formation type into the next. As evidenced by the dull condition (Figure 5), the additional blades of PDC cutters provided the outer shoulder durability necessary to complete the interval with only minimal wear on the PDC cutters and occasional chipping on the gouging inserts.

Generation 3 Pexus designs have also completed over 25 runs in surface applications since late 2015. In one field area in Western Canada, 12 ¼ in. hybrid bits are routinely outperforming PDC bits in a formation of 4 - 10 ksi compressive strength containing sand, shale, and some coarse grained sediments. A search of 11 close offset wells shows that 419 type Pexus hybrid bits achieved an average ROP increase of 69% over 616 type PDC bits in run lengths between 1820 and 2020 ft (Figure 6). The reduced blade count consistently provides the added aggressiveness needed to significantly boost ROP, without sacrificing toughness or steerability.

Figure 5. *Dull condition of a 8 ¾ in. Pexus hybrid bit after completing a challenging reaming and vertical section (left). Dull condition of a 6 ¼ in. Pexus hybrid directional bit after completing a challenging build section (right).*

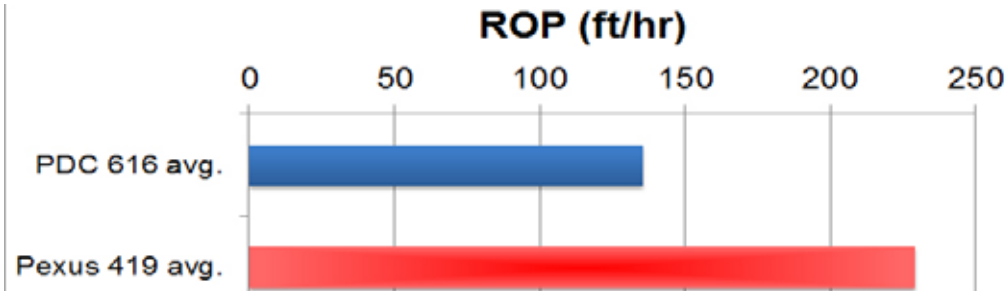

Figure 6. *Average ROP comparison of 11 close offset 12 ¼ in. diameter intervals.*

Conclusion

Since the initial design concept, Pexus hybrid drill bit technology has taken significant strides in its development. Three generations of design iterations have continuously strived for improvement, consistently achieving positive results over hundreds of runs in a wide variety of applications. The hybrid gouging/shearing cutting structure is engineered to provide superior rock fracturing capability, protection, and directional control over conventional drill bit designs.

References

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3. Cookson, C., 'New Drill Bits Boost Efficiency, Safety', The American Oil & Gas Reporter, (April, 2016), pp. 80 - 87.