Advances in PDC Cutter Bits Improve Drilling in Hard, Abrasive Formations

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About 70% of the footage drilled worldwide is performed with polycrystalline diamond compact (PDC) bits. This percentage is projected to increase with the continued pursuit of hydrocarbons and geothermal energy in more challenging environments.

In these more demanding applications, conventional PDC cutting elements have often failed because of formation abrasiveness, impact damage, and thermal fatigue. To improve PDC bit drilling, a tougher, more abrasion-resistant cutter technology is required.

An extensive research and manufacturing effort was launched to develop new technology that would enable a cutter to withstand harder, more abrasive formations. Attention focused on manufacturing processes involving diamond sintering and advanced materials development. The initiative resulted in the development of the Onyx II premium PDC cutter, which has significantly improved abrasion resistance and thermal stability. The cutter has been run in the Travis Peak and Cotton Valley formations in east Texas for Devon Energy since 2010 and has generated improved rate of penetration (ROP) results while significantly reducing cost.

The new cutter represents an evolution of technology, having been introduced two years after the debut of the first generation of the high-performance shearing element. Development of the first-generation cutter was enabled by the use of a proprietary, two-step high-pressure/high-temperature (HP/HT) manufacturing method that allowed PDC bits to drill more footage at higher ROP. With bits fitted with these cutters, intervals that normally required multiple PDC bits to reach total depth could be drilled in a single run in some cases.

Engineering a New Cutter

To advance the technology to the next level, a key objective was to develop a tightly packed, high-density diamond structure that would enable the cutter to achieve better wear resistance and improved thermal stability. Experiments with several diamond grit combinations were made. The mixture of base diamond material with different size distributions was evaluated to achieve the best theoretical packing density. The mixture was then sintered using an extreme HP/HT process. The process produced additional diamond/diamond bridging and networking, compared with the existing cutter manufacturing process. Tests have confirmed that the extreme HP/HT process produces a cutter with improved thermal wear resistance capable of retaining a sharp cutting edge for a longer period than previous cutters.

In the laboratory, the new PDC cutter has demonstrated a 15% to 20% improvement in the resistance of its shearing elements to abrasive wear, compared with the previous cutter (Fig. 1).

Dynamic Modeling System

To fully exploit the enhanced characteristics of the new cutter, a dynamically stable bit body with the proper blade count and optimized cutter placement is required. These factors were achieved by means of an integrated drill-bit design system in which rock sampling and bit performance modeling were used to help create the bit design and cutter layout. With this system, designers can observe how
the bit interacts with actual formations as an integral part of the total drilling system. Engineers can then test and analyze the results of iterative design changes to rapidly advance an engineering concept to a field-proven PDC design.

Field Results in East Texas

The Travis Peak (Lower Cretaceous) is one of the hardest, most abrasive formations in the world. Its high unconfined compressive strength, ranging between 9,000 psi and 32,000 psi, make it ideal for field testing new PDC cutter technology. Evaluation and validation of the new cutter technology could be carried out with a high degree of confidence because of the relative uniformity of drilling programs, and the ability to select offset wells to minimize the number of variables affecting bit performance.

Travis Peak Vertical. In the first field test, a six-bladed, 97/8-in. MSi616PX bit equipped with 16-mm new generation cutters was run below 103/4-in. casing in a vertical interval through the Travis Peak and deep into the Cotton Valley formation. The bit drilled a total of 7,307 ft, reaching the Travis Peak in one run and drilling 1,232 ft into the formation, setting a county ROP record for PDC drill bits at 66 ft/hr. A cost analysis was performed using footage totals, drilling hours, and cost per foot for four direct offset wells with 97/8-in. hole sections.

Bit design, rig capabilities, bottomhole assembly (BHA) configurations, mud properties, run parameters, and wellbore designs were taken into consideration in the head-to-head comparison analysis. Three of the four offset wells required two PDC bits, and the fourth required three bits to complete the interval. For the interval drilled with the new PDC cutter, cost per foot was 26% lower than the average for the offset wells.

Bossier Horizontal. The new PDC cutters were used to drill an interval in a Bossier sand horizontal well, in an area where the formation has an unconfined compressive strength of 9,000 psi to 18,000 psi. The formation is generally encountered at a true vertical depth (TVD) of 12,400 ft to 12,800 ft. For this test, a seven-bladed 61/2-in. MSi713WUPX bit equipped with 13-mm cutters was used to complement a rotary steerable system (RSS) to drill below 78/8-in. casing in the lateral hole section (Fig. 2).

As in the first vertical field test, a head-to-head comparison analysis was conducted for four offset wells, taking into consideration bit design, rig capabilities, BHA configurations, mud properties, run parameters, and wellbore designs. The run was successful, and the bit drilled significantly more footage than the offset PDC bits, resulting in a 20% reduction in cost per foot. The bit was graded 0-1-BT-G-IN-NO-PR, compared with an average of 1-2-WT-NS-IN-NO-PR for a representative competing bit.

Second Travis Peak Run. A second field run occurred in a vertical well in an area where the Travis Peak and Cotton Valley formations have an unconfined compressive strength range of 9,000 psi to 32,000 psi, and the Travis Peak is typically encountered at 6,000 ft to 6,500 ft TVD. The formation is approximately 1,800 ft to 1,900 ft thick in this area. Devon's goal for this test was to drill a 78/8-in. vertical hole section at maximum ROP to the kickoff point with as few PDC bits and trips as possible, preferably reaching target depth in one bit run.

A six-bladed 77/8-in. MSi616UPX bit equipped with 16-mm PDC cutters was run below 133/8-in. casing through the Travis Peak and bottomed in the upper portion of the Cotton Valley sand, before the BHA was tripped for a change-out at the predetermined kickoff point. The bit completed the section in one run at an average ROP of 116 ft/hr, setting a new county record and documenting a 95% increase over the ROP average of 59 ft/hr drilled by PDC bits in four offset wells. In the head-to-head comparison analysis, the reduction in rig time reduced cost per foot by 44%.

Summary

The new cutters have increased total footage and penetration rate capabilities for drilling hard, abrasive formations in the East Texas Basin. This latest advancement in materials science has the capability to help operators reduce PDC bit consumption per hole section and shorten the time to production.