New PDC bit cutters improve wear life and ROP

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ADVANCES IN polycrystalline diamond compact (PDC) cutter technology have resulted in the development of new cutters with greatly improved abrasion properties.

Fixed cutter bits fitted with these new cutters have demonstrated substantial increases in wear life and drilling rates of penetration (ROP) in field tests conducted around the world.

While the faster drilling rates saved rig time, less bit wear translated into greater total footage drilled with fewer bit changes and lower wear rates to BHA tools, resulting in reduced drilling costs for operators.

The newly developed Schlumberger TReX* cutters are designed with an ultra wear resistant layer of diamond at the cutting edge. In the laboratory, the new cutters consistently measure 400% more abrasion resistance than standard PDC cutters, without jeopardizing their impact properties.

This translates into a 45% increase in cutter wear life properties. These laboratory results have been confirmed in numerous field tests conducted worldwide in which the same bit types were compared to those in close offset wells, with the cutters being the main variable.

These field trials achieved greater than 50% improvements in ROPs and section length drilled.

NEW CUTTER TECHNOLOGY

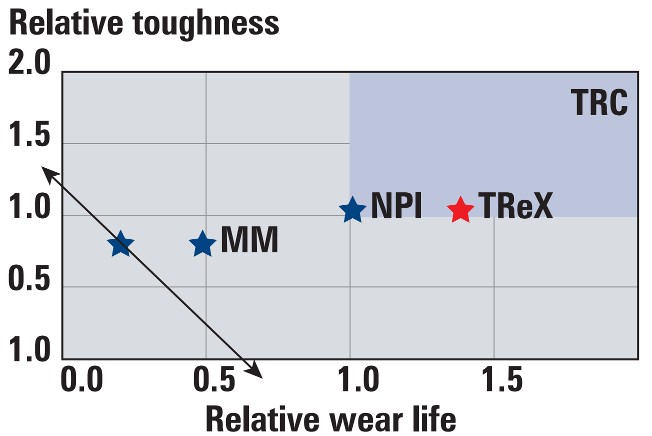
The development of TReX cutter technology signifies a step change in the long-standing efforts by the PDC synthesis industry to develop a material having increased abrasion resistance, or wear life, without sacrificing impact resistance, or toughness.

These properties are influenced primarily by the size distribution of the synthetic diamond microparticles, or diamond grit, which are used in pressing the PDC wafer. The relative particle sizes will define the properties of the PDC in responding to bottomhole drilling actions, with larger particle-sized material being more resistant to impact forces and smaller sizes more so to abrasive wear.

Historical development efforts have found that altering these particle size distributions has served to improve one property, only at the expense of the other.

Depending on the diamond grit size mix, cutters either have been more wear resistant or more impact resistant.

The inverse relationship between toughness and wear life is shown in Figure 1.



PDC technical improvements advance toward the top right corner (TRC) of the wear life vs. toughness plot. TReX technology results in cutters with longer wear life, without sacrificing their toughness.

TReX technology has now succeeded in improving the historic compromise between a PDC cutter's properties of resistance to wear and toughness. However, the technology progressed through several developmental stages in order to overcome the previous PDC cutter limitations.

These stages are illustrated in the aforementioned graph, with technical improvements advancing toward the top right corner (TRC) of the wear life vs. toughness plot (Figure 1).

Successful PDC bit performance depends upon maintaining a sharp diamond edge on each individual cutter throughout the bit run. Although diamond is the hardest known material, it will deteriorate from the impact shocks and abrasive wear that occur during the drilling process.

Even small impact shocks can create micro-fractures that lead to chipping of the sharp cutter edges. Friction and continuous contact with the drilled rock generates heat, resulting in thermal degradation of the diamond and blunting of the cutting edge.

Much effort has been made by the diamond synthesis industry to improve PDC properties over the past three decades, with some significant milestones achieved. The introduction of multi-modal (MM) techniques marked one of the earlier stages of PDC cutter development. MM technology enabled the diamond particle sizes to be more evenly distributed than was previously possible.

This resulted in increased diamond density, which in turn increased cutter abrasion resistance without decreasing impact resistance, thus taking a step toward the TRC of the graph (Figure 1).

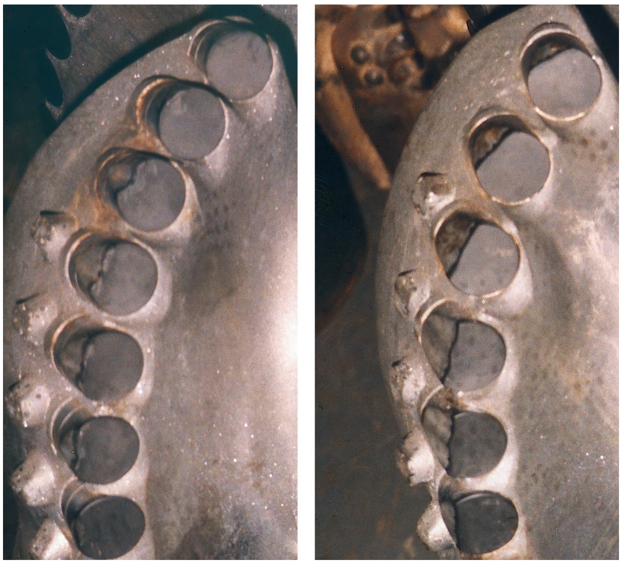
Implementing non-planar interfaces (NPI) comprised the next stage of PDC development. NPI advances focused on de-localizing interfacial stresses and reducing peak stresses, thereby substantially increasing cutter toughness. These significant cutter improvements also are illustrated on the graph with a marked TRC movement.

TReX technology builds on the combination of these and other enhancements to provide a PDC cutter that has the basic property of remaining sharp as it wears, therefore causing the carrier bit to drill farther and faster. The surface of the cutter is a thin layer of diamond that is 400% more abrasion resistant than the lower diamond layer.

Analysis of used TReX bits reveals that the cutters develop interesting wear characteristics, in that sharp lips and flinted edges maintain the bit's capability to drill at an optimum performance level. These self-sharpening features are clearly evident, and they are the main contributors to the outstanding performance of bits that are fitted with the new cutters.

However, it is worth noting that analysis of worn TReX cutters requires care to ensure that the flinted edge is not mistaken for chipping and spalling, which are customary blunt wear features of non TReX PDC cutters.

Consequently, the new cutter technology has enabled wear characteristics to be greatly advanced without negatively affecting impact resistance. The new PDC material keeps cutters sharper while maintaining their toughness.



Bit cutters used to drill the North Sea Flounder and Herring formations, including a limestone sequence, show the significant difference in wear exhibited by the TReX (left) and standard cutters.

Because their design incorporates a lip that might be relatively fragile, TReX bits are preferentially applied in abrasive rather than high-impact applications.

Nonetheless, the new cutters have been successfully applied in a broad range of drilling environments, with impressive results in numerous field applications conducted worldwide. In this article, two areas will be discussed in particular: the North Sea and Australia's Cooper Basin.

NEW CUTTERS IN THE N SEA

The new cutters were initially tested in three North Sea fields for both UK and Norwegian operators. The results of these field trials are discussed in the following paragraphs.

An 8-1/2 in. bit equipped with TReX cutters was used to drill a high-angle, reservoir tangent section in the demanding Britannia formation for a UK North Sea operator.

One of the tougher sections of the formation was a hard, abrasive sandstone containing interbedded mudstones, which had compressive strengths of more than 30 Kpsi.

When drilling through this section, a three-times higher ROP was achieved over a 25% longer reservoir interval than was accomplished in close offset wells drilled with bits fitted with standard cutters.

In another UK North Sea field, a 12 1/4-in. DSX 97 bit fitted with the new cutters was used to drill the Flounder and Herring formations. The drilled section, which included a demanding marl/limestone sequence, was penetrated at almost twice the ROP--89% higher--than a similar section drilled with a standard cutter bit.

The TReX bit showed no wear and was pulled for TD whereas the bit with standard cutters had IADC grade 1:2:PR.

For a Norwegian operator's North Sea well, the new cutters also produced impressive results when drilling the Fangst and Baat Group (Jurassic) sandstone.

An 8 1/2-in. DSX94 bit fitted with TReX cutters achieved increases in drilled footage and ROP of 55% and 25%, respectively, compared to the same bit type fitted with standard cutters that was run in a close offset well.

Both bits were pulled for TD with an equal IADC wear grading. Several other 8 1/2-in. DSX94 bits fitted with the new cutters that were run in this field had comparable results.

However, it is striking that in these and the majority of other test runs, consistent ROP improvements are recorded, thus confirming that TReX cutters remain sharp as they wear.

AUSTRALIAN APPLICATON

In Australia's Cooper Basin, the new cutters increased footage drilled by 38%, thus allowing an operator to penetrate in one trip an entire section that included the challenging Hutton formation.

The hard and abrasive Hutton formation present a significant challenge due to confined compressive strengths ranging from 30-50 Kpsi, with occasional thin beds exceeding 50 Kpsi.

The section prognosis comprises 3,500-4,500 ft of soft claystone, followed by 300-400 ft of Hutton siliceous sandstone. The objective is to have a bit fast enough to maintain high ROPs in the soft section, but tough enough to survive the Hutton sandstone.

A TReX cutter-equipped 6 3/4-in. DSX68 bit drilled a total interval of 4,297 ft, 305 ft of which included the difficult Hutton formation.

While ROP was sacrificed in extending the run, the bit averaged 16.2 ft/hr through this hard abrasive sandstone. In an offset Hutton well, the same bit fitted with standard cutters drilled just 85 ft of the sandstone.

In the previous benchmark for the field, 190 ft of the Hutton was drilled at 20 ft/hr using a different bit equipped with standard cutters.

In additional Cooper Basin bit runs, the new cutter bits have consistently drilled more of this hard rock than bits having standard PDC cutters.

In summary, TReX cutters represent one of the most significant advancements in PDC bit technology in recent years. In numerous field trials conducted worldwide, increased penetration rates and extended bit life have resulted in lower well costs for operators.

While these benefits will continue, it is anticipated that the TReX characteristic of "wearing sharp" will provide other important economic benefits, including more reliable steeribility and a higher quality well bore.

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