In the past, most PDC drill bits had steel bodies. As new materials became available to better customize bits for specific applications and formation, tungsten carbide matrix body bits became popular because of their increased abrasion resistance and durability. However, matrix body bits are problematic in that they are brittle compared to steel, constraining engineers in bit designs for difficult applications. In shales, for example, blades need to be taller and thinner to optimally drill and clean the well bore, but if the blades on a matrix body bit are too tall, they are prone to cracking and failure. As shale plays have become extremely active, steel body bits have resurfaced due to their improved ductility and strength for the type of blade geometry necessary to drill efficiently.

“A tall, thin blade is exactly what we need for fast drilling in shale environments,” said Steve Segal, marketing and technology manager, Smith Bits. “They provide large volume surface areas for cuttings to be quickly evacuated from the bit face.

“Shale is not an abrasive formation,” he continued. “Neither is there a problem with bit erosion because most rigs are not high powered, so abrasive mud is not being forced out of the bit at high velocity; it is being pumped at low velocity. Using steel makes complete sense.”

The bits are designed specifically for drilling curves and laterals in a single run with a relatively low-powered rig, “so it’s extremely applicable for the majority of wells being drilled in North America today,” he said.

**Bit design optimized for shales**

Smith Bits Spear shale-optimized steel-body PDC drill bit is being used in several North American shales such as Marcellus, Haynesville, Eagle Ford, and Barnett, but it is not used in the Bakken due to its abrasive environment. The company also is implementing the bit in emerging international shale plays in Poland and Argentina.

The bit body was designed to accomplish several things, including high ROP and efficient cuttings removal. The latter is achieved by better hydraulics though a directed mud flow, a bullet-shape steel body, tall and thin blades, and a reduced bit body diameter. The second generation of the company’s ONYX cutters – ONYX II premium PDC cutters – also increases the bit’s performance because they retain their sharp edges longer as a result of optimizing the density of the diamond structure. This is accomplished by synthesizing the diamond under increased HP/HT conditions and advanced processes to enhance thermal conditions.

Directed mud flow is designed to clean debris from the cutterface so a sharp cutter edge is always at the rock surface. The mud flow also keeps the cutters cooler to prevent thermal breakdown. The bullet-shaped body with reduced body diameter streamlines the bit. The greater area around the body allows the bit to pass over or through a cuttings bed without blade packing and nozzle plugging. The bits use smaller (11- to 13-mm) cutters with a shallower depth of cut for improved directional control with no adverse effect on ROP, according to the company.

The bit was specifically designed to be used with PDM, and the company worked closely with PathFinder, the Schlumberger North American land directional drilling company, to optimize the bottomhole assembly (BHA) and bit.

“When we are running motors and MWD systems from PathFinder, we understand the bottomhole assembly being used,” Segal said. “We model that exact BHA to determine the required cutting structure on the bit.”

The company also is developing a shale specific bit to work with the Schlumberger PowerDrive Archer high build-rate RSS.

Another feature of the bit is its Lo-Vibe inserts, which are strategically placed behind the shoulder and gauge cutters at a predetermined exposure to manage the magnitude of instantaneous cutter loading and bit torque. Lo-Vibe technology is
specifically designed to limit torque fluctuation in directional applications and helps mitigate vibration to achieve higher ROP and improved bit durability.

“We are trying to limit the ability to bite into the formation,” Segal explained. “Typically on a BHA, weight stacking might become an issue, and if you don’t have those features the cutters can be forced into the formation, leading to cutter damage.

“The Lo-Vibe feature basically helps us mitigate that and calms the bit,” he continued. “It helps reduce or minimize vibrations at the bit, and results in higher ROP and longer lasting cutters without any sacrifice to ROP.”

Second-generation cutters

There are some important differences between the two generations of ONYX cutters, which are manufactured by the company. The ONYX II cutter is synthesized using advanced manufacturing techniques including a proprietary two-step process that gives the ONYX II superior abrasive wear and resistance to thermal degradation compared to previous cutter generations, the company said. A different diamond powder is used in the second iteration and is pressed at high pressures and high temperatures of more than 1 million psi and 1,000°F to form a polycrystalline diamond compact bit. “We begin with different raw material for the ONYX II,” Segal said, “and there is a different manufacturing process that is even higher pressure than the ONYX cutter to form a more dense and compacted cutter. It then goes through various post process treatments to make the cutter as durable and resistant as possible.”

To evaluate improved wear characteristics of the cutters, a controlled laboratory comparison was conducted on granite. The second-generation cutter showed a 20% reduction in wear flat area with minimal chipping and degradation as measured against earlier ONYX cutters. The company noted two runs in Sublette County, Wyoming. In one run, a 6-in. MDI516 bit equipped with ONYX II cutters outperformed the best offset well that was drilled with a bit with first-generation ONYX cutters. The bit with ONYX II cutters drilled 4,775 ft in 78.5 hours at a rate of 60.8 ft/hr compared to 3,900 ft drilled in 79.4 hours at an average rate of 49.2 ft/hr.

While the ONYX II cutter is the company’s latest generation and provide several features leading to better performance while increasing cutter life, these particular cutters are not always used on the Spear bit. It depends on the application. The first-generation appropriate cutter and bit type.

“For example, a run in the Haynesville Shale with the Spear fitted with ONYX cutters saved the operator US $365,000,” he noted.

Case histories

In the Haynesville well, an operator wanted to reduce the number of days and trips required to drill the 6¾-in. production interval by drilling the curve and lateral sections in one run. Previous bit designs were aimed at either the curve or the lateral, necessitating a trip to change out the bit and adjust the bend angle. Bits that target the curve section have strong build tendencies and predictable toolface control, but often deliver low ROP in the lateral. Conversely, bits for the lateral section are built for aggressive, fast ROP but increase the risk of improper build rates in the curve section. The use of two bits and extra trips meant higher field development costs. Engineers needed to design a PDC bit that could be efficiently run on a PDM with a lower bend angle while achieving the desired build rates (8° to 14°/100 ft), ensure good directional control, and deliver high ROP in the lateral. Long lateral drilling in shale plays presents additional challenges such as cuttings accumulation at the bottom of the well, which impedes access to fresh rock and results in low ROP, packed blades, nozzle plugging, and stick/slip.

The operator provided valuable BHA data, mud properties, and offset run information for focusing the design. Close coop-

The Spear shale-optimized steel-body PDC drill bits have been specifically designed to improve the economics of shale plays by efficiently drilling a curve and a long lateral hole section, minimizing bit balling and short runs, improving ROP, and enhancing directional control.

(Illustration courtesy of Smith Bits, a Schlumberger company)
eration between the various groups resulted in new PDC bit technology, the Spear 6¾-in. SDi611 drill bit. The shale-optimized steel-body PDC bit, together with a 2° fixed bend steerable motor, drilled the 6,063 ft of curve and horizontal intervals in one run, setting a new Haynesville horizontal ROP record of 49.7 ft/hr. No other bit had drilled the entire curve and lateral sections at that high rate.

Based on comparisons with two direct offset wells, the total drilling time was reduced by 124 hours. In addition to saving the operator $365,000 in rig time and bit costs, the improved performance shortened time to production, allowing more wells to be drilled in a given period.

In the Eagle Ford Shale, operators experienced costly non-productive time (NPT) as a result of multiple runs needed to drill curve and lateral hole sections. An operator wanted a PDC drill bit that would increase ROP and total footage capabilities in the 8¾-in. curve and lateral hole sections while providing good directional control at maximum penetration rates. Engineers tailored specific Spear PDC steel-body technologies to solve the application issue. Smith Bits developed a specific Spear PDC bit optimized for the Eagle Ford Shale drilling application. The 8¾-in. SDi513 on a Pathfinder steerable motor drilled 6,904 ft of curve and lateral hole section in one run at a record ROP of 64.83 ft/hr, representing the fastest curve and lateral run for the operator in the Eagle Ford. Based on a comparison with the best offset run, the Spear bit saved the operator $46,780 in rig time. Compared to the next four best offsets, the run saved significantly more rig time and lowered the overall drilling costs associated with multiple trips/bits required to complete curve and lateral hole sections.

In the Marcellus, EOG Resources wanted to reduce the number of days and trips required to drill the 7¾-in. curve and lateral sections by drilling both sections in one run and reduce NPT caused by motor and MWD failures. EOG provided BHA data, mud properties, and offset run information. Smith Bits engineers designed a PDC bit that could be run on a PDM with a lower bend angle, allowing rotation and a high ROP in the lateral section. At the same time, however, the bit had to be capable of achieving the necessary build rates of 8° to 16°/100 ft while ensuring good directional control in the curve. Long lateral drilling in shales presents additional challenges such as cuttings accumulation at the bottom of the well, which impedes access to fresh rock and results in lower ROP, packed blades, plugged nozzles, and stick/slip.

The Spear 7¾-in. SDi513 steel body PDC bit specifically designed for the Marcellus in combination with a fixed bend steerable motor drilled the 6,241-ft curve and horizontal interval in one run, eliminating trips for PDM adjustments and bit changes after landing the curve. Reduced bit and tool vibration solved the issues of PDM and MWD failures. The bit's bullet shaped steel body and other design features alleviated buildup of cuttings in front of the bit. In comparisons with the average offset wells, total drilling time was reduced by 2.7 days, saving EOG $175,000 in rig time and bit costs. The shortened time to production also allowed more wells to be drilled in a given period.