Step Change in Performance: Upgraded Bit Technology Improves Drilling Economics

Operators in the Gulf of Mexico (GOM) are constantly looking for ways to reduce the costs of drilling development wells. A new steel-tooth (ST) roller-cone bit with an advanced metal-seal bearing has achieved this goal and is having a significant effect on drilling economics. Improvements in bearing life, seal reliability, and cutting-structure durability have resulted in more time on bottom, giving the operator the confidence to use the new roller-cone bits in long directional hole sections.

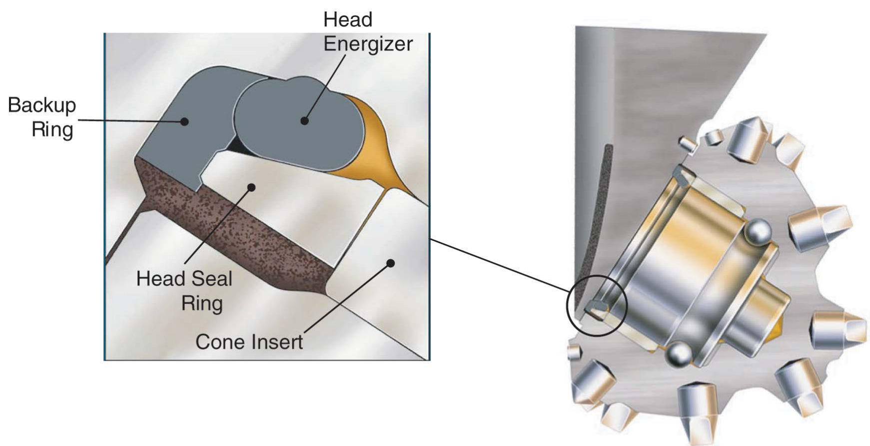

Fig. 1—SEMS bearing with enlarged view of seal package.

Introduction

With large regions of the GOM rapidly becoming mature provinces, operators are looking for ways to reduce the costs of drilling development wells. Most of the wells drilled are directional, and heavy water-based drilling fluids often are required in the intermediate hole sections. Relatively high bottomhole temperatures combine with high bottomhole pressures and balling shales to present a challenging drilling environment. Operators strive to increase rate of penetration (ROP), maximize hours on bottom for each bit, reduce risk, and complete the section with fewer bits to reduce the number of trips.

Improved roller-cone bits with an innovative single-energizer metal-seal (SEMS) bearing were introduced in 1998 **(Fig. 1).** A step change in bit life was realized, yet it took a year or two for operators in the GOM to gain sufficient confidence in the new ST bits to run them harder and leave them in the hole longer. By 2000, operators routinely were achieving runs as much as twice as long as was typical with the predecessor elastomer-sealed ST bits, particularly at higher rotary speeds (e.g., 175 to 275 rev/min). In 2000, enhanced ST cutting structures were introduced to complement the SEMS bearing **(Fig. 2).** The new ST cutting structure provided longer tooth life by improved tooth wear resistance and reduced tooth breakage.

This article, written by Assistant Technology Editor Karen Bybee, contains highlights of paper SPE 103074, "Step Change in Performance: Upgraded Bit Technology Significantly Improves Drilling Economics in GOM Motor Applications," by ***B. Grimes,*** *SPE, and* ***B. Kirkpatrick,*** *Hughes Christensen, prepared for the 2006 SPE Annual Technical Conference and Exhibition, San Antonio, Texas, 24–27 September.*

GOM Drilling Environment

The GOM drilling environment is one of the most diverse in the world. With exploration and development programs taking wells to ever greater depths, the demands placed on ST roller-cone bits and their sealed-bearing systems become increasingly severe. The increased service life and reliability of rotary-steerable systems and top-of-the-line motor assemblies allow them to successfully drill long, complex well paths, which increases the directional challenges for roller-cone bits. Both concentric and eccentric hole-opening technologies place unique loading conditions on roller-cone bits when they are used as pilot bits.

The drive toward improved drilling economics in the GOM demands that individual bits drill farther and faster than in previous years. Drilling these challenging hole sections with fewer bits per section is the ever-present goal. Sealed-bearing roller-cone bits cannot drill increasingly longer hole sections unless their demonstrated bearing life and reliability justify confidence on the part of the operator to leave the bit in the hole longer.

Many GOM well programs include $8^1/_2$-in. hole sections in the 12,000- to 18,000-ft measured-depth (MD) range, with mud weights (MWs) from 17 to 19 lbm/gal. Such high mud weights require high solids content in the mud. The combination of MD and high MW results in very high bottomhole pressures. The main challenge from a bit perspective is being able to withstand these high pressures exerted on the bearing seals, as well as effectively resisting the deleterious effects of mud solids.

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Fig. 2—New $8^1/_2$-in. IADC Code 117 ST bit.

Wear Analysis

A research project was initiated in 2003 to improve the sealed-bearing life and reliability of $8^1/_2$-in. Intl. Assn. of Drilling Contractors (IADC) Code 117 ST SEMS bits. Ten $8^1/_2$-in. IADC Code 117 dull SEMS bits used in the GOM were examined. The following bearing-seal-related wear/failure modes were observed to be the primary life-limiting factors in this drilling environment.

1. Worn metal-seal faces—the metal-seal system has a finite, relatively constant wear rate that typically provides longer service life than elastomer-sealed bearings. The position of the relatively narrow polished seal band can be measured accurately. The seal band starts out on the outside of the seal face and slowly wears across the seal face to the inside diameter, at which point the seal is totally consumed. The subject dulls experienced an average 65% metal-seal wear after 400,000-revolutions service.

2. Tribological examination of the narrow metal sealing band indicated that galling often occurs between the two mating stainless-steel seal faces. Galling is an adhesive wear mechanism associated with similar materials in sliding contact under pressure. Small wear particles are transferred back and forth between the wear surfaces, which can result in a roughened, smeared appearance. Galling can produce decreased sealing efficiency and advanced wear rates in metal-seal applications.

3. An elastomeric O-ring energizer is used to seal and anchor the metal seal ring to the head section. The energizer also urges the metal-seal ring against the polished end of the cone seal insert, which constitutes the second metal-seal face. The head seal ring and energizer normally are stationary on the head bearing, while the cone seal insert rotates with the cone so that all relative rotational sliding occurs between the two metal seal faces. Drilled fines, mud solids, and mud packing that make their way into the head seal ring and energizer cause the head seal and energizer to rotate on the head section. This is an undesirable condition because the O-ring energizer ceases to be a static seal and temporarily becomes a dynamic rotating seal. Energizer slippage quickly degrades the energizer to the point that seal failure occurs, even with remaining metal-seal-face life.

4. The specially shaped low-modulus backup ring (BUR) is positioned on the mud side of the O-ring energizer. The BUR contributes to the total seal-face load and serves as an additional anchor to keep the head seal ring and the energizer from rotating. It also occupies a volume that routinely filled up with mud and cuttings in the older dual metal-seal-face design. The BUR may become damaged from excessive mud packing in service; it also will wear very quickly if energizer slippage occurs.

Metal-seal-face wear and/or galling, energizer slippage, and damaged energizers and BURs will all result in eventual seal failure, whereby grease is lost from the sealed-bearing system and drilling mud and cuttings contaminate the bearing. Seal failure in service will result in accelerated bearing wear and cone drag, which produces cutting-structure wear and damage. Continued operation in a seal-failed condition will produce progressive wear of the head and cone bearing surfaces, eventually resulting in cone loss in the hole. Cone loss is extremely undesirable in the GOM because of the associated downtime and fishing services to retrieve the cone. A consistent, long-life bearing with a very low failure rate will allow an operator to drill wells much more cost-effectively, with a low risk of failure.

New Sealed-Bearing Design

The new SEMS2 sealed-bearing package was developed with specific features to address the wear/failure modes observed. The metal-seal cross-sectional width was increased approximately 20%. Because metal-seal wear is relatively linear, this results in a 20% increase in potential seal capacity.

A proprietary surface treatment was applied to the metal-seal face on the cone seal insert. The surface treatment produces an extremely hard, thin layer on the metal-seal face, which significantly decreases the seal wear rate and reduces the friction coefficient at the seal faces. Galling is essentially eliminated because the two seal faces are no longer identical materials. The surface treatment also allows high seal-face loads to be specified for high sealing efficiency, yet the high hardness and low friction result in a greatly reduced seal wear rate. The 10 SEMS dull bits from the GOM averaged 65% seal wear in 400,000 revolutions, while eight new SEMS2 bits averaged only 43% wear in 500,000 revolutions.

The new BUR was stress engineered by use of finite-element analysis to provide a more robust shape with improved ability to keep out debris, and it is seated in an improved seal gland. Thus, the new BUR can protect the metal seals better from mud packing over an extended service life. Redesigned seal-energizer-seat geometry improves sealing efficiency, maintains constant face loads during axial cone movement, and provides increased seal-face loads to resist energizer slippage better and increase seal efficiency. An advanced pressure compensator and proprietary grease formulation combine to minimize torque, reduce heat, and increase bearing load capacity.

Case Study 1

Case Study 1 called for drilling interbedded sand/shale sequences offshore Matagorda Island. The objective was to develop technology that would allow the operator to reduce drilling costs by eliminating the nonproductive time consumed tripping for new bits while increasing the amount of on-bottom time with each bit.

After an in-depth analysis of offset information, the service company's engineers selected an ST bit that would drill the $8^1/_2$-in. section efficiently. Key components included the premium SEMS2 metal-seal package for superior bearing reliability and patented hardfacing technology to ensure cutting-structure integrity throughout the run. The newly designed $8^1/_2$-in. IADC Code 117 was run with exceptional results, drilling 2,820 ft of formation at

43.4 ft/hr and completing the section in 65 hours. The new SEMS2 metal bearing performed exceptionally well, while the enhanced cutting structure transitioned efficiently between the sand/shale sequences without issues. Two offset wells required two and three SEMS bits to complete the same hole section; thus, the SEMS2 well realized cost savings of U.S. $59,000 and $156,000 to the same depth vs. the offset wells. An SEMS2 bit was run on another well and drilled 834 ft farther than the first SEMS2 run, for a total of 3,711 ft in 83 hours at 44.7 ft/hr and 946,000 revolutions. This demonstrates consistently good performance for the SEMS2 bits in this application.

Case Study 2

Case Study 2 was in a very abrasive sand/shale interval in Vermilion Parish, Louisiana. The challenge was to develop technology that would allow the operator to reduce drilling costs by reducing the number of bits required to complete the 8½-in. hole section and decreasing occurrences of lost cones. The service company selected an ST bit that would drill the 8½-in. section efficiently. Key components included the premium SEMS2 metal-seal package for superior bearing reliability and patented hardfacing technology to ensure cutting-structure integrity throughout the run. The newly designed 8½-in. IADC Code 117 was run in the well with excellent results, drilling 1,197 ft in 97 hours at 12.3 ft/hr for 1,048,000 revolutions. An offset well required two SEMS bits to drill the same section; these two bits averaged 370 ft in 34.3 hours at 10.8 ft/hr for 370,000 revolutions. The new SEMS2 ST bit realized a cost savings of U.S. $36,000 to the same depth as the offset well, then drilled another 631 ft. As a result, the operator was able to drill the interval to an even greater depth with one less bit at 14%-higher ROP. Additional SEMS2 bits have been run in this field, continuing the performance improvements and cost savings over the SEMS bits. The SEMS2 bits have averaged 47% greater revolutions, with a seal effective ratio of 80% vs. 72% for the SEMS field average, with a 65% greater average life to seal failure. This type of differentiable performance gains the trust of operators and enables longer bit runs to be achieved with confidence. JPT