Advances in steel tooth technology improve drill bit performance in GOM applications

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DESPITE SIGNIFICANT PDC encroachment into traditional roller-cone applications, steel tooth (ST) bits still drill approximately half of the total footage in the US Gulf of Mexico. Selection of PDC or ST bits is largely driven by the drilling fluid that is used. PDCs are generally favored in oil-base or synthetic-base muds, while ST bits are favored in water-base mud (WBM) applications. The ST’s resistance to balling in WBM and desirable steerability characteristics will continue to make them viable tools in GOM applications for the foreseeable future. Despite advances, the basic ST cutting structure has remained fundamentally unchanged for four decades.

An R&D effort convinced the bit manufacturer a new ST cutting structure could be developed that could deliver substantial improvements in ROP without sacrificing durability. The result is a new high-velocity steel tooth (HVST) bit with the industry’s first significant new ST cutting structure arrangement in more than a decade. The patented pyramid-shaped tooth is a key element of the aggressive cutting structure and maintains its like-new condition longer before dulling. The new technology is having a beneficial impact on drilling economics in the GOM by delivering unmatched ROP, greater footage and better dull condition than conventional ST bits.

HISTORICAL

Operators are constantly looking for ways to systematically reduce the costs of drilling development wells with improved technologies that deliver increased performance and decreased risk. Most offshore GOM wells drilled are directional, and drilling fluids with high mud weights (MW) are often required for well control purposes in the intermediate hole sections. The resulting extremely high bottomhole pressures and sticky, balling shales make it difficult to increase bit ROP. Operators strive to improve their drilling economies with increased ROP; maximized footage drilled per bit, and fewer bits to complete each section in order to reduce the number of trips and associated non-productive time.

While PDC bits continue to replace many traditional tungsten carbide insert roller cone applications in medium-hard to hard formation US land drilling applications, steel tooth bits have maintained a relatively constant one-half of the total footage drilled in the US GOM for several years.

One of the primary considerations is mud type: Oil-based muds and synthetic-based muds enable PDC bits to drill at relatively high ROPs in the sticky shales without excessive bit balling, while ST bits drill well in the much less expensive water-based mud systems. Another significant factor is that ST bits have continued to improve significantly over the last decade, primarily in bearing seal life/reliability and cutting structure longevity.

However, the basic cutting structure design — that is, the number of rows of teeth and the number of teeth within rows — has gone largely unchanged for the last 50 years. This translated into similar ROPs for bits in the new condition and maintained ROPs over longer intervals, since tooth wear in service was reduced with the material and design improvements; however, these improvements did not translate into increased ROP.

Drilling research was initiated to increase ST drilling rates through innovative cutting structure arrangements. The most promising of the new arrangements was then engineered for manufacturability, in part by developing improved welding techniques for applying hardfacing to the cones. Recently developed design and material improvements for better gauge holding were also incorporated in the new design, along with a new shirttail protection scheme. After extensive field testing with resulting iterative design and manufacturing improvements, the new high-velocity steel tooth bit is now being exploited by operators in the US GOM.

GOM APPLICATION

GOM exploration and development programs are taking wells to ever greater water depths and measured depths. The increased service life and reliability of modern rotary steerable systems and high-end motor assemblies allow them to successfully drill long, complex well paths, which ratchets up the requirements on all bit types. The overall well economics often require the use of water-based muds rather than costlier oil- or synthetic-based muds. ST bits enjoy distinct advantages over PDC bits in WBM due to their lower initial price, their ability to recover from bit balling situations, their steerability, and their high build-up rate potential. The current high offshore rig rates can be offset by drilling wells in fewer total hours at higher ROP. The drive to improve drilling economics in the GOM demands that
individual bits drill farther and faster than in previous years. Drilling these challenging hole sections in fewer hours with fewer bits per section is the ever-present goal, until eventually all hole sections can become one-bit sections.

Typical GOM well programs include 8 ½-in. hole sections in the 12,000-ft to 18,000-ft measured depth (MD) range, with mud weights ranging from 15 to 19 ppg due to well control considerations. The combination of high mud weights and great depths often results in very high bottomhole pressures. High bottomhole pressures effectively strengthen the sand and shale formations, which may aggravate bottom- and/or bit-balling tendencies, and increase the wear rate on the cutting structure. These factors tend to limit ST drilling rates and tooth life and are difficult to overcome with simple operating parameter changes (WOB, RPM, flow-rate). Operators required a new ST bit that can drill faster without sacrificing durability or longevity.

**NEW STEEL TOOTH DESIGN**

A research project was initiated to improve the ROP potential of 8 ½-in. IADC Class 117 steel tooth bits run in GOM applications. A cross-functional product development team was assembled to develop the new HVST bit. Two 8 ½-in. diameter prototype concept bits were designed and manufactured for preliminary laboratory drilling tests and benchmarked against the current market leading ST bit. One of the prototypes appeared to have strong potential from both drilling performance and manufacturability perspectives, so it was selected for further development.

The new HVST design, named FastMax, uses pyramid-shaped teeth in the inner rows and chisel-shaped heel rows with shorter crests than standard. Similar tooth projections and cone offset to the baseline bit were specified, but two more rows of teeth were added. The crest lengths of the pyramid-shaped teeth are much less than conventional chisel-shaped inner rows. This provided the room required for the additional rows of teeth.

The pyramid teeth also provided room for designing wider spaces between the middle rows of teeth; this has been determined to be beneficial from an anti-balling standpoint. A new anti-tracking row was also developed whereby a middle row on one cone is given approximately twice the normal number.
of teeth to break up the large tracking build-ups that often occur on conventional ST designs.

An offshoot of the HVST team developed a new ST bit with significantly increased wear resistance for drilling longer or multiple hole sections in highly abrasive applications. This team developed an improved gauge design to resist rounding and reduce cone shell erosion between the heel and gauge teeth. An improved shirrtail protection scheme was also developed.

FIELD PERFORMANCE

Numerous FastMax bits were run in the GOM and land operations in south Louisiana, as well as south and east Texas. To date, the bit sizes that have been tested are 8 ½ in., 8 ¾ in., 9 7/8 in., 12 ¼ in. and 17 ½ in. Test results have been positive, with improved ROPs along with increased footage, decreased tooth wear and strong gauge holding ability. The new shirrtails are also displaying improved longevity and durability.

CASE STUDY 1

Location: Mississippi Canyon, offshore Louisiana

Formations: Frio sands and Hackberry shale

Challenge/objective: Drill out 9 ½-in. hole from 4,608 ft and drill to TD at 9,000 ft while holding 46° inclination in 11 ppg WBM. The previous offset well on the same platform made it to TD in one run by drilling 4,225 ft in 84 hrs at 50 ft/hr with a conventional premium metal seal 117 ST bit; this established the benchmark. The objective was to drill the section at a higher overall ROP.

Results: The operator agreed to test one of the new 9 ½-in. HVST bits in this application. Moderate operating parameters were used, and the first HVST bit run completed the section by drilling 4,192 ft in 76 hrs at 55 ft/hr, for an average ROP increase of 10%. The operator decided to drill the following well with another HVST bit, and this time more aggressive operating parameters were used. The second HVST bit completed the section by drilling 4,302 ft in 50.5 hrs at 74 ft/hr, 46% faster than the benchmark. Total drilling time was reduced by 24.5 hrs, saving the operator $139,000. Both bits came out of the hole in good dull condition.

CASE STUDY 2

Location: Calcasieu Parish, La.

Formations: Frio sands and Hackberry shale

Challenge/objective: Drill out from 3,500 ft in WBM through the Frio sands and the plastic, sticky Hackberry shale in which standard ST bits and PDC bits often have low ROPs.

Results: The operator agreed to test a 12 ¼-in. HVST bit in this interval. The plan was to drill with the HVST bit down to 7,100 ft and then pull it to finish the section with a PDC bit; however, after observing the excellent ROP through the top of the Hackberry shale, the operator kept the HVST bit in the hole. The bit ended up drilling 4,865 ft to a depth of 8,360 ft at 61 ft/hr. This was more than double the footage compared with the best offset run in the area for a total savings of $55,000.

CASE STUDY 3

Location: Cameron Parish, La.

Field: West Chalkley Area

Formations: Interbedded sand and shale

Challenge/objective: The challenge was to drill a vertical section out from under surface casing to the next casing point at approximately 9,000 ft depth with higher ROP and fewer bits than the offset, which required three IADC 115 ST bits.

Solution: Operator agreed to run the new 17 ½-in. FastMax bits on a trial basis. The bits also featured a second-generation metal seal bearing package. Two HVST bits completed the section with improved ROPs, saving four drilling days and one bit trip compared with the three-bit offset well, for a total savings of $170,000. The bit came out of the hole in good shape.

CONCLUSIONS

• FastMax drills significantly faster than conventional ST bits in typical US GOM drilling applications. It also displays improved bit life, durability; and gauge holding ability; drilling longer sections with less overall tooth wear and gauge wear than conventional ST bits.

• Moderate WOBs and good hydraulics are needed for FastMax to realize its full ROP advantage.

• The higher ROP and longer bit life of the new HVST bit results in substantial drilling cost and risk reductions by drilling entire hole sections in fewer rotating hours, increased footage drilled per bit, reduced flat time due to fewer bit trips, and fewer ST bits to purchase.

• The improved drilling economics realized with the new HVST bits should enable ST bits to continue drilling a large portion of the total footage in the US GOM, despite continuous improvements in PDC bit performance.