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Drilling technology: Increasing transfer value

The search for new energy sources has focused renewed attention on reducing costs and improving drilling efficiency. One company is conducting scientific research to launch innovative technologies to address the challenge.

NILS REIMERS, Tomax

New low carbon energy sources and CO_2 storage requires deep drilling technology. The challenge is to lower the cost (or increase efficiency) sufficient to make drilling more economical. Recent developments in well construction technology, which is supported by the work of the drilling community and international academia, has revealed significant potential for efficiency improvements. These findings will enable operators to apply these new tools and best practices to deliver value for a low-carbon future.

Improvements and disappointments. PDC bits (**Fig. 1.**) came to dominate the oil field about 30 years ago. The iconic roller-cone bit and diamond impregnated turbine grinders are still used, but they are much less efficient. The most significant improvement to PDC technology over the years has been a leaching process to strengthen the cutter's structure at temperature. This, in turn, has improved wear resistance. A PDC bit makes a fine cut, and a select number of blades provide an overlapping rock-removal process. This principle makes a steady axial reference important for efficiency. Conversely, the drill string is simultaneously subject to both compression and tension at different positions along its length. Such axial variability has a negative effect on a PDC bit, too. Even so, this method still outperforms all other solutions for deep drilling.

Fig. 1. The predominant method for well construction is drag bits equipped with PDC cutters.

Scientific consensus. Over the last decade or so, leading scientists from both academia and oilfield services have gathered for an international colloquium on nonlinear dynamics and control of deep drilling systems. These events have established a common reference in terms of the relevant physics, mostly formulated around mathematical models. Several universities and scientists have worked on the problem of the fine cut in combination with a long string. The relevant mathematical model (**Fig. 2**) of this situation reveals oscillations in multiple directions.

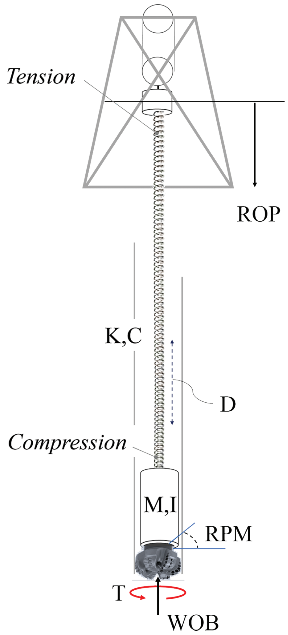
For example, the string is softer in the torsional direction than axially, so the torsional oscillations are comparatively slower. Torsional oscillation or stick-slip is well known to drillers and is typically transmitted to the surface by the MWD system. Axial instability is not so easily measured. It may have several sources: the trailing pattern of the bit blades, pressure pulses in the pipe or brake operation at the surface. Regardless, the onset of slip cycles in the axial direction strongly affects the cut. In real life, the same can be observed with a hand-drill; in hard materials, a small variation in loading stops progress.

With a long string, more weight on bit (WOB) will increase rate of penetration (ROP) but also drive up axial amplitude. Eventually, the ROP will stop responding to more WOB. Adding WOB from this point, known as the founder point, will cause the bit to wear fast from overheating. Drilling mud of good lubricity is key to this situation and crucial for PDC performance. With the problem now defined in mathematical terms, it is possible to add a control algorithm, or, in practical terms, a regulator, to the system to counteract axial instability and its consequential inefficiencies.

Immediate results. In 2005, the Norwegian technology start-up, Tomax, presented a regulator to be located between the drill pipe and a PDC bit. Its purpose was to prevent severe torsional stick-slip. At the time, stick-slip was causing costly downtime in new downhole tools. The new regulator was launched as the Anti Stick-Slip Tool (AST); internal gearing would make the AST alter its length and, hence, WOB as a function of torque, whether increasing or decreasing.

Controlled tests of the AST gave the desired effect on stick-slip. They also revealed an improvement in drilling effi-

Fig. 2. Example of basic model input. The string itself is modelled with spring constants in two directions; K, C and also dampening D.

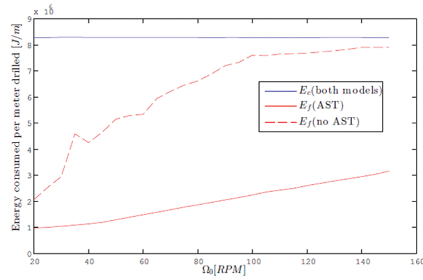


ciency and reduced bit wear. The results were noticed by the project sponsors, Norsk Hydro and Statoil—now Equinor. The published data from the first years of the AST in Norway attracted interest in the concept from Shell Research in Rijswijk. Shell was sponsoring an ongoing study on control systems at the Eindhoven University of Technology (TUe) that also involved quite a few key scientists from the deep drilling colloquium. At Shell's request, the scientists at TUe incorporated the AST principle into their existing mathematical drillstring model. The output was compared against a benchmark. On the first attempt, the results replicated the field observations.

With a proven model, the details of the AST's influence on the axial slip cycle in terms of added efficiency and reduced wear could now be studied: the AST algorithm would indeed interfere with the relative timing of the load cycles. The shifts in timing reduced the losses to friction quite significantly. Obviously, more energy was then available to cut rock, **Fig. 3.** Initial results showed an efficiency gain in the range of 30% to 40%. The reduction in friction promised a doubling in durability.

Rapid growth. The model has since been elaborated in more detail: aspects such as axial dampening and sidewall

Fig. 3. Output from mathematical model. Less energy consumed with AST is from reduced friction. The gap can be translated directly to reduced wear. Source: MSc thesis of P. Blatter, TUe.



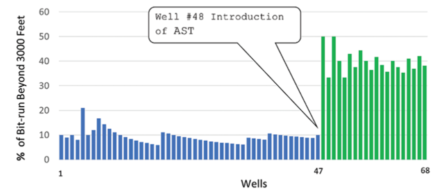
friction and deviation have been incorporated and analyzed. The output has been used to improve the tool, itself. The contributions from an increasingly effective AST tool have been well- received in areas with a focus on drilling performance. These include remote Atlantic deepwater operations and the U.S. shale plays. The use of AST has increased year-on-year for the last five years and made AST the fastest-growing new drilling technology.

More than half of all rotary steerable operations in the Permian basin now use AST. The results from academia are easily verified in the Permian, with large series of identical wells. As an example, Cimarex shared their internal statistics in 2018, **Fig. 4.** Their presentation was based on 68 wells and showed how the AST influenced drill bit durability: four times as many bits would drill beyond 3000 feet (1,000 m) after the AST was taken in to use.

Potential is evident. Not all oil fields have identical wellbores for comparison. To obtain information on the AST's contribution in a single well, Tomax during 2020 fielded a new solution, based on micro-electronics. The system records the real workload of the AST; more precisely, the converted energy at the central helix. The recorded data are useful for verifying the value of including the tool and for optimizing the choice of bits going forward.

In the early summer of 2021, Tomax fielded an AST with a new level of perfected spring deflection characteristics. The operator matched the prototype with the most aggressive bit available. The well had low deviation and was drilled for appraisal purposes. This drilling system turned out to break all existing section speed records on the Norwegian

Fig. 4. Statistical study on drill bit durability from inclusion of the AST. Blue bars are wells before the AST was included. Source: Cimarex Energy, Denver, Colorado.



Continental Shelf. The bit crossed several geological periods and 2,000 vertical meters in 24 hrs. Having set the record, the PDC bit emerged with minimal wear and was graded 0-0-IN. Further results from the same R&D program point to efficiency gains equivalent to a doubling of daily footage on average, compared to a stiff system.

With such numbers, the oilfield drillers certainly have something to bring to the table for the future exploitation of new underground energy sources.

Recognition. The modeling of various aspects of the AST contribution and its effect on controlling the rock cutter interface has been the work of many students and scientists. And the list of contributors is still growing. However, special mention must be made of the group of professors overseeing the research, who have played vital roles on a global scale: Nathan van de Wouw, Department of Mechanical Engineering, Eindhoven University of Technology; Emmanuel Detournay, Department of Civil, Environmental and Geo-Engineering, University of Minnesota; and Henk Nijmeijer, Delft Center for Systems and Control, Delft University of Technology. Along with their fellow scientists in the deep drilling colloquium, this group is definitely "at the right place, at the right time" in terms of helping our industry to prepare to meet new challenges. **WO**

NILS REIMERS is founder of Tomax AS. Before Tomax, he served in various management positions for companies in the Aker group. Mr. Reimers spent his first decade with MWD pioneers Teleco and later Baker Hughes. He was formally recognized by the Norwegian Petroleum Museum for his contributions to advancements in drilling technology from 1990 to 1997. He has a BSc degree in petroleum engineering from the University of Stavanger.