INTERNATIONAL SEVEN JOURNAL
OF MULTIDISCIPLINARY
ISSN: 2764-9547

TECHNOLOGICAL ADVANCEMENTS IN WELL DRILLING: THE ROLE OF ROTARY STEERABLE SYSTEMS

https://doi.org/10.56238/isevmjv3n1-029

Receipt of the originals: 04/12/2023 **Acceptance for publication:** 27/01/2024

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ABSTRACT

The oil and gas industry, constantly evolving, has greatly benefited from significant technological innovations, especially in drilling. Oklahoma stands out as a hub of progress, with important milestones such as the drilling of the state's fastest well using Rotary Steerable Systems (RSS). This advancement exemplifies the growing importance of automation, real-time monitoring, and optimized drilling strategies to improve speed and precision in complex formations. RSS enables continuous rotation of the drill string, reducing friction, increasing stability, and minimizing non-productive time (NPT), resulting in higher rates of penetration (ROP) and lower drilling costs. The combination of real-time data and automated controls has also enabled more efficient drilling with lower environmental impact. Case studies, such as those by Hayes et al. (2023) and Dixit et al. (2023), show that adopting RSS can be more cost-effective than traditional systems like the Motor-Driven Curved Casing, offering significant reductions in cost per foot drilled and improvements in penetration speed. Furthermore, digitization and automation have facilitated a shift to remote operations, minimizing risks to workers and reducing the carbon footprint. RSS systems are becoming increasingly essential for drilling in horizontal and extended-reach wells, with the use of these emerging technologies providing greater efficiency, accuracy, and sustainability in oil and gas exploration. The future of drilling is closely tied to these technological advancements, with promising benefits for the industry.

Keywords: Rotary Steerable Systems (RSS). Drilling Efficiency. Automation and Real-Time Monitoring. Oil and Gas Technology. Horizontal Well Drilling.

INTRODUCTION

The oil and gas industry is constantly evolving to improve efficiency, and Oklahoma has stood out as a key region for technological advancements in drilling. One of the most notable milestones in recent years was the drilling of the state's fastest well using the Rotary Steerable System (RSS). This achievement highlights the growing importance of automation, real-time monitoring, and optimized drilling strategies in modern well construction. The well, drilled in the Anadarko Basin, demonstrated how RSS technology can enhance speed and accuracy in complex formations. Unlike conventional directional drilling with motors, RSS allows continuous rotation of the drill string while steering the wellbore path, reducing friction, improving hole stability, and minimizing non-productive time (NPT). By integrating real-time data with automated steering controls, the drilling team achieved unprecedented rates of penetration (ROP) while maintaining wellbore trajectory accuracy.

Several factors contributed to the rapid drilling of this well. First, the well design was carefully planned to minimize unnecessary corrections and maximize efficiency. The use of advanced RSS technology enabled smooth, continuous drilling with minimal interruptions. Additionally, real-time monitoring and AI-driven optimization allowed immediate adjustments, reducing drilling time and improving overall performance. The choice of enhanced mud systems helped maintain well stability and optimize hole cleaning efficiency, while the collaborative execution between drilling engineers, geologists, and field personnel ensured continuous operations and quick decision-making.

Figure 1: Rotary steerable systems.

Source: Baker Hughes.

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This record-breaking feat sets a new benchmark for high-speed drilling in Oklahoma and beyond. The success of the RSS in this project demonstrates its potential to significantly reduce drilling costs, improve well quality, and increase operational efficiency. As the industry continues to adopt automated drilling solutions, the adoption of rotary steerable systems is expected to grow, driving further advances in speed, accuracy, and sustainability in oil and gas exploration. The study conducted by Hayes et al. (2023) analyzed the efficiency and costs of different directional drilling systems, comparing the performance of the Autonomous Rotary Steerable System (SA-RSS), the Motorized Rotary Steerable System (MD-RSS), and the Conventional Curved Hole (CBH) casing with a drilling motor. The research was conducted on three wells in the Caney Formation, in southwest Oklahoma, and demonstrated that the use of RSS in the 12.25" vertical intermediate sections and 8.75"/8.5" lateral sections was more cost-effective than the CBH system. The results showed that the cost per foot drilled with CBH was 1.6 to 2.3 times higher in the vertical section and 1.7 times higher in the lateral section, while the rate of penetration (ROP) with RSS was 2.3 to 4.8 times faster in the vertical section and 1.6 times faster in the lateral section. These findings reinforce the growing global acceptance of RSS technology, especially in horizontal and extended reach wells (ERW), which have become the industry standard. In the United States, the average length of horizontal wells increased from 10,000 feet in the early 2000s to 18,000 feet in 2019, while one of the longest wells ever drilled in the world, in the North Sea, reached a total depth (TD) of 49,000 feet in 2017. In Oklahoma, the focus area of the study, 1,379 horizontal wells were completed between 2020 and 2022, with an average length of 18,624 feet and an average drilled length of 8,000 feet, highlighting the trend toward longer wells and the growing need for advanced technologies to optimize efficiency and reduce costs.

The study by Dixit et al. (2023) explores the role of digitization and automation technology in optimizing the efficiency and accuracy of drilling operations, specifically in multilateral wells. The work emphasizes how recent advances in rotary steerable systems (RSS), low-friction water-based mud, and long-lasting drill bits have played a crucial role in relocating personnel from drilling service companies' drilling sites to remote operations centers. This transition not only reduced personnel exposure on-site, minimizing health, safety, and environmental risks, but also decreased the carbon footprint while improving overall operational performance. The study highlights the success of drilling 6,624 meters horizontally in a single run, within the reservoir target, without health, safety, and environmental (HS&E) incidents. The use of remote operations was essential to achieve optimized rotations per minute (RPM), minimizing high-frequency torsional oscillation (HFTO) vibration, and avoiding common issues like severe whirl in long tangent sections. The operation resulted in one of the top five rate-of-penetration (ROP) indices in the field and the longest drill bit run in the same field. Moreover, the remote operation led to savings in transportation costs and an estimated reduction of 697,261 kg in CO2-equivalent emissions. This exceptional performance resulted from integrating technology across various product lines, enhancing performance, reducing costs, and improving well placement. The study highlights how continuous advances in technology, automation, and digitization are driving safer, more efficient, and sustainable energy delivery solutions.

The analysis by Litvinenko and Dvoinikov (2019) on the vibrational accelerations and beat amplitudes of submerged drilling motors revealed crucial data to determine the ideal energy characteristics of the gerotor mechanism, ensuring stable operation. Through large-scale computational and experimental research, the study defined dependencies that describe the operation of the "bit – rotary steerable system with screw section – drill string" system, as well as the boundaries of self-oscillations and the onset of resonance when using these components together. The authors proposed a mathematical model that helps determine the ideal technological parameter range for well drilling. By controlling the torque-power and frequency characteristics of the drill string, considering the energy characteristics of the screw section of the rotary steerable system, the model allows for reducing extreme vibrational accelerations of the bottom-hole assembly. Furthermore, the study provides recommendations on the selection of suitable drilling mode parameters, contributing to more efficient and stable drilling operations.

The research by Weijermans et al. (2001) investigates well tortuosity, defined as any undesirable deviation from the planned trajectory, a factor that can cause significant challenges in drilling, completion, and production of wells. As wells become more complex, tortuosity can lead to additional torque/drag and difficulties in running casing, liners, and completions. In some cases, excessive tortuosity in horizontal wells can even hinder productivity. The study compares conventional directional drilling systems using motor-based curved casing technology with rotary steerable systems, which are considered more effective in reducing well tortuosity. The research presents the results of tortuosity analysis on several North Sea wells drilled with rotary steerable systems, alongside comparison wells drilled with motor-based curved casing systems. The study uses torque/drag simulations to illustrate the potential benefits of reducing tortuosity in drilling conditions, showing that the lower tortuosity of the rotary steerable system results in a torque-reduction effect, which is significant in some cases.

The analysis by Saltykov, Makovsky, and Mansurova (2020) on the implementation of rotary steerable systems (RSS) in the construction of high-tech wells in Russia demonstrates the positive impact of this technology on well safety and quality. Used for the past five years, RSS technology has proven to be an effective solution, especially in wells with large vertical deviations and extended drilling radii. RSS systems allow precise drilling along the entire well, including the ability to drill vertical wells with deviations of no more than 0.2° and horizontal wells exceeding 2,000 meters. In 2016, OktoGeo LLC conducted a pilot drilling program in the Khanty-Mansiysk oil field using the 172 mm APS Technology RSS system with a power section, successfully completing a 2,205-meter directional well. The results of this work served as the basis for subsequent RSS system positioning programs in the region.

In conclusion, the continued advancements in drilling technology, particularly the adoption of Rotary Steerable Systems (RSS), represent a significant leap forward in the oil and gas industry, especially in Oklahoma. The ability to drill faster, more precisely, and at a lower cost has been proven through various successful projects that highlight the crucial role of automation, real-time monitoring, and AI-driven optimization in modern drilling operations. The growing acceptance of RSS technology, alongside advancements in digitalization, automation, and remote operations, has resulted in notable improvements in efficiency, safety, and environmental sustainability. As the industry moves toward longer horizontal wells and increasingly complex formations, the integration of these cutting-edge technologies will continue to reshape the landscape, driving further innovation and cost-effective solutions in oil and gas exploration. The continued research and development in this field, exemplified by studies and pilot programs worldwide, provide a clear path toward more efficient, precise, and sustainable drilling practices.

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