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(Review Article)

Driving sustainable success: Achieving emission reductions and operational excellence in ultra-deepwater drilling

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Abstract

In the context of advancing sustainability goals, an operator faced challenges in drilling an ultra- deepwater exploration well offshore Malaysia, prompting the need for a solution to mitigate risks while minimizing environmental impact. Through a comprehensive life cycle analysis, emissions were quantified, and an emission baseline was established, laying the groundwork for achieving sustainability key performance indicators (KPIs). Baker Hughes' recommendation of their DELTA TEQ™ low-impact drilling fluid system, coupled with the unique rheology modifier additives, not only addressed operational challenges but also facilitated a significant 21% reduction in emissions. This integrated solution underscores a proactive approach towards sustainability in the oil and gas sector, leveraging data-driven insights to drive environmentally conscious practices and achieve overarching sustainability objectives.

Keywords: Ultra-deep; Drilling; Emissions; Sustainability; Life Cycle Analysis

1. Introduction

Ultra-deep-water drilling refers to the process of exploring and extracting oil and gas resources located at depths greater than 1,500 meters (5,000 feet) below the ocean's surface. This type of drilling presents unique challenges due to the extreme conditions, including high pressures, low temperatures, and complex geological formations. These factors necessitate specialized equipment, technology, and expertise.

2. Key Challenges in Ultra-Deep-Water Drilling

- **Extreme Pressures**: At significant depths, the hydrostatic pressure is immense, requiring robust and precisely engineered equipment to withstand these conditions.
- **Low Temperatures**: The seabed temperature in ultra-deep waters is near freezing, which can affect the performance of equipment and fluids.
- **Geological Uncertainty**: The subsurface formations are often less understood, making it challenging to predict and manage drilling conditions.
- **Remote Operations**: The deep-water environment is far from shore, complicating logistics, maintenance, and emergency response.
- **Safety Risks**: The high-pressure and high-temperature (HPHT) conditions increase the risk of blowouts and other catastrophic events.

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3. Importance of Drilling Fluids in Ultra-Deep-Water Drilling

Drilling fluids, or muds, play a critical role in overcoming the challenges of ultra-deep-water drilling. Their functions and importance are amplified in this context due to the extreme conditions encountered.

3.1. Specific Considerations for Ultra-Deep Water Drilling Fluids

- **High-Performance Properties**: Fluids must be able to perform under high-pressure and high-temperature conditions without degrading or losing their functional properties.
- **Temperature Stability**: Drilling fluids need to remain stable and effective in both the cold seabed environment and the high-temperature conditions encountered deeper in the wellbore.
- **Environmental Concerns**: Given the remote and sensitive nature of deep-sea environments, fluids must be formulated to minimize environmental impact in the event of a spill or discharge.
- **Enhanced Rheology**: The fluids must maintain optimal viscosity to effectively carry cuttings to the surface and provide adequate pressure control throughout the drilling process.

3.2. Innovations in Drilling Fluids for Ultra-Deep Water

- **Nanotechnology**: Incorporating nanoparticles into drilling fluids can enhance their properties, such as improving thermal conductivity, increasing shale inhibition, and reducing fluid loss.
- **Advanced Polymers**: New polymer additives are being developed to improve the rheological properties and thermal stability of drilling fluids.
- **Eco-Friendly Additives**: Innovations focus on reducing the environmental impact of drilling fluids, making them more biodegradable and less toxic.
- **Real-Time Monitoring**: Advanced sensors and monitoring systems allow for real-time analysis of drilling fluid properties, enabling immediate adjustments to maintain optimal performance.

4. Case Study

An operator planned a vertical, ultra-deepwater exploration well at a water depth of 2,884 m (9,462 ft)—the deepest waters to date offshore Malaysia for the operator. The operator secured the drillship to drill the well to a target depth (TD) of 4,707 m TVD (15,443 ft TVD) through several carbonate sections with wellbore stability risks.

The operator needed a rheological stable synthetic-based mud (SBM) while drilling the 17-in. and 12 1/4-in. sections, which both possessed narrow pore pressure/fracture pressure windows that raised the risk of fluid losses or wellbore collapse. The cold subsea temperature of 40°F (4.4°C) also risked raising the plastic viscosity (PV) and gel strength of the SBM, which would reduce pump efficiency and rate of penetration during drilling operation; increase surge and swab pressure limits trip speed; all will extend operation time and increase drillship costs, extend drilling times, and increase drillship costs. The customer required a fluid alternative that would help drill the well to TD and deliver a hole size suitable for optimal data logging and well testing.

As part of an integrated drilling solution, Baker Hughes recommended its DELTA-TEQ™ low-impact drilling fluid system, a SBM engineered to extend drilling in narrow windows. In addition, the DELTA-MOD™ rheology modifier additive would provide improved emulsification, wetting, and dispersing properties to the mud system.

4.1. Designing the optimal fluid solution

The Baker Hughes team conducted pre-job fluid design work to develop the optimal DELTA-TEQ formulation. The team evaluated the system's rheological properties at three different temperatures—40°F, 80°F, and 120°F (4.4°C, 27°C, and 49°C)—to ensure that the fluid remained stable and flowed freely at any temperature encountered during the drilling operation.

The operator's fluid engineer reviewed and approved the proposed mud system and requested that an extra mud engineer be present on the drillship while drilling with the DELTA-TEQ system.

Delivering stable wellbore to TD

After drilling the 42-in. and 26-in. upper hole sections with seawater/Hi-Vis and 11.5 ppg DKD mud, the drilling team switched to the DETA-TEQ fluid to drill the 17-in. and 12 1/4-in. sections. The addition of DELTA-MOD rheology modifier in the DELTA-TEQ system helped maintain a flat rheology profile at low temperatures to manage equivalent circulation density and maintain a stable wellbore. The mud system achieved good hole cleaning in both sections, with no check trip or wiper trips required. Neither section exhibited any hole fill or restrictions while tripping in casing to bottom.

DELTA-TEQ fluid helped drill the narrow window sections within eight days, with no instability issues, fluid rheology problems, or fluid losses. This allowed the operator to save 3.5 days in rig time, capturing $1.75 million USD in drillship cost savings and 21% CO_2 emissions reduction at the rig site. All sections were drilled successfully while delivering a clean, stable wellbore for efficient wellbore logging and future field planning.

4.2. Challenges

Successfully drill to TVD of 15,443 ft (4,707 m) through a narrow pore pressure/fracture pressure window. Minimize operating costs while drilling at a water depth of 9,462 ft (2,884 m)—the deepest waters to date for the operator. Avoid downhole losses while drilling through carbonate formation section. Deliver high-quality wellbore for wireline logging runs to collect formation pressures, fluid, and core samples.

5. Results

Delivered an integrated drilling solution that includes: DELTA-TEQ system, AutoTrak™ RSS

Advanced LWD and MWD services (OnTrak™ LWD, SoundTrak™ LWD, SeismicTrak™ SWD, ZoneTrak™ LWD)

Successfully drilled 17-in. and 1/4-in. sections within eight days. Maintained flat rheology profile at seabed temperature of 40°F (4.4°C), with no gelling. Reduced CO_2 emissions by 21% at the rig site by drilling 3.5 days early vs plan (operational experience). Saved the operator an estimated $1.75 million USD in drillship costs.

6. Conclusion

Ultra-deep water drilling represents one of the most challenging frontiers in the oil and gas industry. The extreme conditions demand highly specialized drilling fluids that can ensure safety, efficiency, and environmental protection. Advances in drilling fluid technology, including the development of SBMs, HPWBMs, and innovative additives, are critical to the success of these operations. As exploration and production push into deeper waters, the role of sophisticated drilling fluids will continue to be a pivotal factor in overcoming the technical and environmental challenges of ultra-deep water drilling.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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