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Downhole geophysical data acquisition during reverse circulation drilling for mining

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SUMMARY

Measurement While Drilling (MWD) and Logging While Drilling (LWD) tools acquire geophysical and operational data from directly behind the bit during drilling operations. Traditionally, such tools have only been integrated into mud rotary drilling systems used in the oil and gas industry and are not available to the mining industry, where reverse circulation (RC) is the prevalent drilling method.

A joint venture between Wallis Drilling and Qteq was formed to develop tools that acquire geophysical data while using RC drilling systems. In this paper, we present drillMAX, the world's first MWD tool for use in RC drilling.

Key words: MWD, LWD, Borehole Logging, RC Drilling, Geophysics.

INTRODUCTION

Measurement While Drilling (MWD) and Logging While Drilling (LWD) tools are being used by the oil and gas industry to acquire geophysical and operational data from behind the bit during drilling operations using mud rotary drilling systems. Some data can be transmitted back to surface to allow real-time steering, target confirmation, drilling optimization and geophysical evaluation of the resource body.

Reverse Circulation (RC) drilling is more prevalent in the iron ore mining industry due to faster penetration rates, lower costs and the ability to obtain clean, on-depth formation samples. Due to the high shock environment and minimal space available for instrumentation, no MWD or LWD tools compatible with RC drilling are available. Instead, the iron ore industry relies on assays of cuttings and post-drilling wireline logs to obtain geophysical and borehole information. These logs include natural gamma, gyro survey, dual density, sonic, image, borehole magnetic resonance, magnetic susceptibility, resistivity, caliper and downhole spectroscopy.

Wallis Drilling and Qteq have formed a joint venture to develop MWD and LWD tools for the mining industry that can acquire geophysical and operational data during drilling operations. This has resulted in drillMAX, the world's first MWD tool for use in RC drilling. Coupled with drillHUB, a rig-based sensor system, this tool enables drillers and remotely operating geologists to make real-time decisions about depth and target penetration. The basic data (natural gamma and gyro survey) replaces the need for standard wireline tools and, with some additional processing, geophysics answers such as rock hardness can be calculated.

METHOD AND RESULTS

RC drilling uses dual wall drill rods rather than conventional single wall drill pipe. The extra annulus (between inner and outer drill rods) imposes severe constraints on space available for downhole instruments incorporated in the drill string. RC drilling also relies on use of percussion hammers, which generate enormous shock and vibration that far exceed the rating of conventional MWD systems. Furthermore, the compressed air travels through the drill rods at high temperatures, exceeding 100°C, imposing additional restrictions on the instrumentation that can be deployed. We overcame all these restrictions through the design of miniaturised, ruggedized and temperature rated instrumentation, as well as through the development of a vibration isolation system that protects the delicate instrumentation from the shocks and vibrations that occur in the drill string. The instrumentation is mounted on a specially designed carrier, which can sustain the forces and torques that occur in the drill string, while providing enough space for the air to pass through and for the mounting of electronics, instrumentation and the power pack.

Boreholes drilled by the mining industry are relatively shallow and follow simpler vertical or near vertical trajectories. While these simpler borehole designs neutralise some of the benefits derived from use of LWD in the oil and gas space, the inventory of such boreholes drilled annually, even within specific basins, is very substantial. At present, after each new borehole has been drilled, an inclination and azimuth survey tool is deployed on wireline to log borehole trajectory. One or more additional wireline runs are then performed to log various geophysical properties. Acquiring these measurements while drilling the boreholes creates situation where the geologists and geophysicists can make decisions to optimise drilling programs. It also eliminates need for some or all the subsequent wireline runs and associated costs. The monitoring and post-drilling analysis of bottom hole assembly (BHA) dynamics will also guide optimisation of RC drilling parameters for subsequent boreholes, thereby reducing rig time and cost for these boreholes.

The remoteness of many mine sites poses an elevated journey safety risk to personnel travelling to these sites. Advanced sensing technologies and cloud-based Big Data ecosystems allow the mining industry to remotely gain a deeper insight and understanding of their assets. Building on the successful development of the drillMAX MWD tool, we are developing the next generation 'plug-and-play' LWD technology,

drillMAX Live, that can be deployed by the rig crew, with MWD/LWD data transmitted from downhole to geologists situated at remote command centres and/or client offices. Eliminating the need for download of the data at the end of the MWD run and with the downhole power generator, also eliminating the need for batteries.

drillASSAY will include advanced LWD sensors such as nuclear magnetic resonance and neutron induced GR spectroscopy. The power requirements for these additional sensors will be met through a downhole power generation system. The downhole data, together with the data acquired using the rig-based sensor system drillHUB, will be transfer to the cloud, processed and made available remotely to all stakeholders (clients, geologists) for immediate analysis and interpretation.

CONCLUSIONS

drillMAX, the world's first RC MWD Tool, will enable mining companies to monitor borehole trajectory and assess the lithology of formations penetrated by boreholes drilled using RC drilling techniques. This actionable data, along with measurements acquired from other sensor types and transferred to the surface using a wireless telemetry system currently under development, will enable these companies to fully characterise elemental composition and mineralogy (replacement for ASSAY), clay content, pore structure, free vs bound fluid content and fluid type in real-time. Additionally, it will enable the optimisation of RC drilling programs. This capability will also reduce the need for subsequent wireline logs and improve safety performance through reduction in rig site headcount.