OWD® - OPTIMERING UNDER BORRNING
OWD® - OPTIMISATION WHILE DRILLING

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Introduction

LKAB Wassara has been a driving force behind new technological development in drilling since the end of the 1980s, when it invented the water-driven downhole drilling hammer. It has since constantly challenged traditional methods with new innovative solutions. Productivity demands have forced development in new technologies, and the possibility to drill long and straight holes has been a huge step in this direction. The next major technology leap for LKAB Wassara is to bring its mechanical products into the digital age. As part of this process, the launch of a data logging, parameter optimization and autonomous drilling system, baptized O.W.D. - Optimization While Drilling, is now taking place.

LKAB Wassara's OWD® system is a sensor and steering system that aims to minimize energy inefficiency in percussive drilling through active control of rig drilling parameters. Through intelligent signal processing, the OWD® system can calculate how efficient energy use is in order to optimize drilling performance and improve productivity. There is an ongoing struggle to improve drilling performance and productivity and it stretches from product development by drilling equipment manufacturers to site drilling for and by the drill operators.

Long-term methodical tests in LKAB mines have shown that with the OWD® system activated, drilling performance (ROP Rate of penetration) can be increased by just over 10% for production drilling on rigs of the latest model from market leading manufacturers, and up to 30% on manual drilling rigs. In addition, it can be seen that a more efficient use of supplied energy leads to reduced wear on drilling steel consumables as well as reduced vibrations, which in turn leads to reduced maintenance of drill rigs. Reduced energy consumption is ultimately also directly linked to reduced CO_2 emissions and operational costs.

Background

LKAB Wassara water-powered hammer is a Down-The-Hole (DTH) hammer directly connected to the perforating drill bit. DTH technology outperforms top hammers in energy transmission efficiency with no power loss over the drill string. This simple fact enables DTH hammers to operate at far longer borehole depths. LKAB Wassara hammers can be used for borehole sizes ranging from 60 to 254 mm. The hammers are running at a water pressure up to 180 bar generated from a high pressure pump.

The LKAB Wassara DTH hammer remains the most environmentally friendly percussion drilling method in existence today. Powered by water and using no oil for lubrication, it causes no contamination of water, air or surrounding formations. Water incompressibility is a key factor allowing the features of the LKAB Wassara hammer,

not least its string pressurization and ramp up times. It also affords major energy cost-savings compared to air DTH technology and reduces the energy demand for powering the hammer. Water also acts effectively in suppressing any dust created during drilling. Higher drilling pressure, cleaner hole finishes, lower losses and higher efficiency can and should practically be possible to achieve. Any exceptions have given us cause to examine.

Rigorous, long-time data collection on the operation of water-powered hammers, even when possible, hasn't always fulfilled the standards of diligence needed for deep and correlated analyses and investigative insights into what might be hindering their full potential from being achieved. For more than 30 years, Wassara have supplied water-powered hammers not only to LKAB mines but also to external markets in unique setups and applications improving drilling performance and quality. Now with the OWD® system, it is possible to further trim and tune our hammer operations to perfection and full potential.

Fault causes with percussive drilling have been many and varied: customer overenthusiasm, complex setups in demanding formations, unexpected parts failure, wrong drilling parameters, water quality, operator levels of proficiency, reluctance to change, non-adherence to recommendations and operation guidelines as well as sheer matters of physics. The tasks of gathering evidence and deducing faults have at times been nearly impossible. Any forthcoming, duly collected MWD data, when available from rig manufacturers supporting such features have been rig-centric and taken at surface excluding any hammer-specific parameters such as DTH Frequency, Pressure drops or actual bottom-hole RPMs. Other important information such as BHA setup, drill string constitution, mechanics and transfer functions and other intermediate forces and factors, including Torque, bit and insert diameter have not been any more readily available. The correlated and interdependent nature of these parameters has only made complex matters worse. It all amounted to being a long shot from even beginning to think in closed-loop automation terms and that was clearly not an ideal spot for field leaders in the industry.

Developments

In an effort to address these shortcomings and as a direct spin-off from LKAB Wassara's undertaking on the Future drilling system project within LKAB, the first open-loop system variants of LKAB Wassara OWD® were born.

Ruggedized sensor systems placed on rigs using LKAB Wassara hammers were developed with a view to being used by field technicians during the initial setup phases of drilling operations to external customers but not only.

Figure 1. LKAB Wassara OWD® controlling Future drilling system coiled tubing rig.

These units would also serve as the first loggers and evidence collectors in cases when there was little less than a penciled day-log to go by. Utilising a cutting-edge wireless accelerometer pair and operated remotely, OWD® 1.0 started as little more than a glorified frequency counter, albeit a really needed one at the time. The task of optimisation was as yet vaguely defined and it rested with the operator, whose job was to make sure that continuous parameter adjustment were made to increase ROP and reduce wear and tear. A tall order to ask and definitely no mean feat, considering all the other activities that operating a rig entailed and in some cases still does. OWD® 1.0 could at best be termed an open-loop hybrid.

Revisiting water incompressibility made it possible for OWD® version 2.0 to log incoming water pressure and hammer frequency at the same time, while also offering the possibility of an in-field session reports and recommendations for ideal hammer frequency and RPMs. The hurdle of open-loop and operator engagement however, still remained.

Figure 2. LKAB Wassara OWD® stand-alone unit in open-loop mode and its closed-loop counterpart in auto mode continuously regulating rig parameters.

Alongside new technology, out also rolled our cut-out-and-keep quick guides to upstarting customers and the dyed-in-the-wool veteran drillers, which were met as expected, with varying degrees of skepticism. The realisation that no ideal values and

target-frequency curves would ever replace acquired field lore and habits was not a difficult one to make.

Breakthrough

For all the novelty and ease of deployment that OWD® 1.0 and 2.0 offered, the task of parameter optimization remained unsolved, complex, and with incomplete data at hand, also quite distant. The breakthrough came in the form of what would later be called The Wassara Factor (Wf) - a patent pending compound metric that measures drilling inefficiency derived from vibration spectral data and which seemed to behave in remarkably similarly fashion to established metrics used in the Oil and Gas world. The difference resides in the simpler and economical way in which Wf is derived and consecutively manipulated in order to calculate the ideal drilling parameters to apply to rigs using Wassara hammers. Wf is used to manipulate a combination of data collected from both rig and hammer in order to calculate optimal rig parameters and feed them back to the rig. The outcome is automation in real-time for best hammer performance and increased ROP. As it turns out, a few welcome derivatives follow alongside.

Figure 3. LKAB Wassara OWD® rig control unit and its field portable kit version.

While testing the theory on our Coil Tubing rig, we found that Wf plotted against ROP result in either a minimum or a point of diminishing return. In other words, there exists a strong relation between a reduced Wf and increased ROP, as exemplified by rod times measured in seconds, up to a formation-determined local minimum. Initial data indicated a relationship but couldn't discriminate between causation and correlation.

A two-month long test spread over many drifts, blast hole fans and grades of iron ore in the LKAB mine in Kiruna would help dispel any doubts about the nature of that relationship.

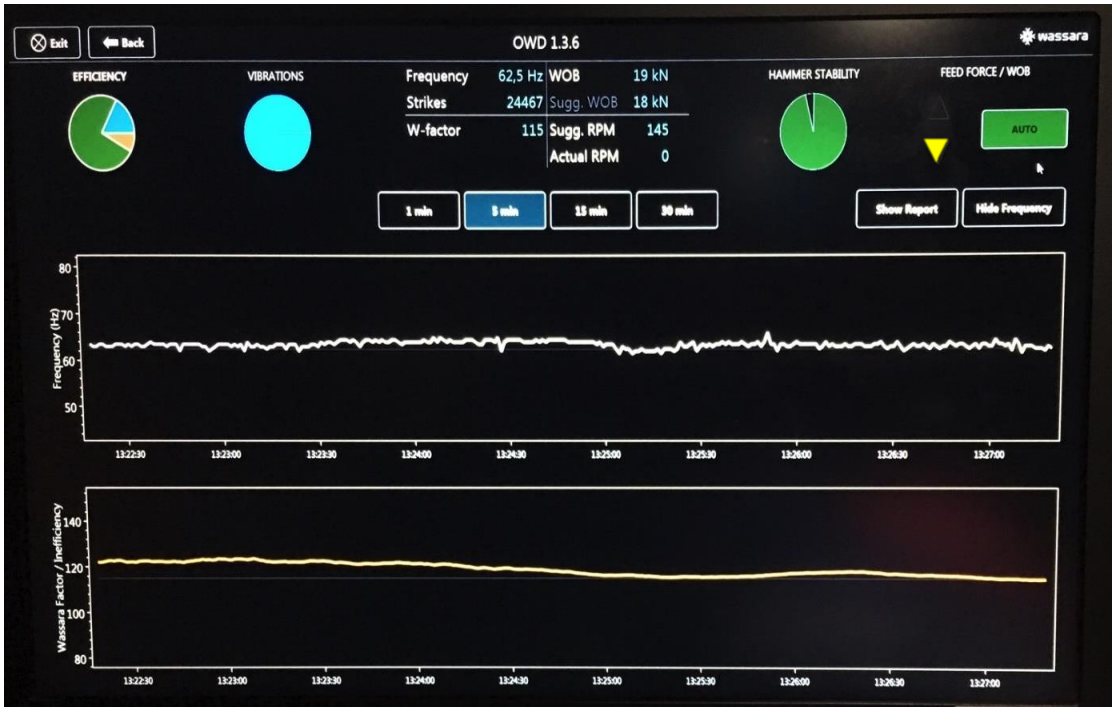

Figure 4. LKAB Wassara OWD® in action keeping hammer frequency constant and in range while gradually reducing drilling inefficiency parameter Wf.

The rules governing the control loop were set for keeping the hammer frequency within recommended range of our product specification guides, reducing inefficiency to a formation minimum and keeping hammer stability at over 90%. By solving for optimal parameters governed by well-established relations, the control loop we employ adjust rig parameter values for Feed Force, RPMs and Incoming Water Pressure at regular 5 second intervals.

Side-by-side comparison tests of the OWD® system activated versus rigs in fully automatic mode showed that drilling performance measured by (ROP) had increase by just over 10% in the case of the former compared to production drilling performed by latest model rigs from market leading manufacturers. Retroactive data analysis indicated that performance could be increased by as much as 30% on LKAB Wassara's own custom-built manual drilling rigs. In addition, the energy bill per meter was lower with the OWD® system activated. Optimal energy usage visibly reduced bit wear. Overall rig vibration levels were also reduced. Tests are ongoing to quantify the longevity of bit and hammers and the effect that would carry on rig maintenance bills.

Parameter	OWD®	Rig-Auto
Rod Times Range (s)	109-259	112-388
Rod Time Average (s)	158	176
Rod Time std dev (s)	20,1	30,1
ROP Average (m/min)	0,78	0,71
Median Frequency (Hz)	65,8	64,2

F MAD (+/- Hz)	3,2	8,52
Wf average (units)	200	1132
WOB average (kN)	14,2	18,8
ROP improvement (%)	11.3	---

Table 1. OWD® improvements over automatic drilling in production drilling within LKAB

Future Potential

The LKAB Wassara OWD® system works on the principle of relative inefficiency for DTH hammers. As such, it is hammer and formation independent and works equally well for water-powered hammers as for pneumatic ones. In its current version (1.3) it can interface with CANbus, serial and OPC communicating rig control systems. Future versions of the OWD® will hopefully come as service implementations of the algorithm on rig platforms open to integrating the solution in software.

Apart from delivering increased ROP at lower energy costs and reduced wear of consumables, it can also help with formation change detection, act as a logging and reporting tool as well as a learning tool. It most certainly has been all of the above for us at LKAB Wassara.

References

www.lkab.com
www.wassara.com