Utilizing sensor technology in drilling optimization

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ABSTRACT: Global climate goals have increased the need to reduce CO2 emissions and material waste in the mining industry. Rock drilling, being the first phase of the mining process, affects the whole chain from bedrock to crushed stone. Modern sensor technology provides a new level of visibility to the drilling process, enabling a reduction of CO2 emissions and material waste. Sandvik Mining and Rock Solutions is pioneering in this field of technology with the RockPulse® product. The product provides direct online stress wave measurement enabling fact-based adaptation to varying rock conditions and optimization of drilling parameters. RockPulse enables finding the optimal percussion power and the reduction of harmful stress waves, which increases the penetration rate and the effectiveness of rock drilling while reducing tool consumption. The RockPulse system has been verified to enable annual reductions of several tons of CO2 emissions per equipment.

Keywords: climate goals, sensor technology, drilling optimization, rock knowledge.

1 INTRODUCTION TO DRILLING OPTIMIZATION

RockPulse®, a product of Sandvik Mining and Rock Solutions, represents modern sensor technology which can be of great use in optimizing drilling. Sensitive sensors produce millions of data points from each hole drilled, which enables optimization of drilling settings on a completely new level. The system has proven to be able to significantly improve hole quality, while reducing tool consumption and improving efficiency. Efficient rock drilling is the first step in reducing CO2 emissions in the rock excavation process.

1.1 Issue definition

The global climate goals aim to reduce CO2 emissions drastically in the coming few years. The goal is to limit the global warming to 1.5 degrees Celsius or to at least well below 2 degrees Celsius compared to pre-industrial levels (United Nations 2015). Finland, the homeland of Sandvik top

hammer drilling equipment, aims to be carbon neutral by 2035 (State treasury, Republic of Finland, 2022).

Mining presently accounts for 4 % - 7 % of global greenhouse gas emissions of which 1 % is from scope 1 and 2 (McKinsey 2020). The Scope 3 emissions are also greatly contributing factor for the mining sector. McKinsey estimates that most of the emissions from mining sector comes from coal mining (at 3 to 6 percent of global emissions). It is inevitable that the mining industry will need to use all tools available for reaching the climate goals. Therefore, all innovations enabling the reduction of CO2 emissions should be considered.

The drilling process highly impacts the overall process efficiency in mining and construction processes. Fuel and tool consumptions are part of the evident CO2 sources. Slightly less evident source, yet significant, is the amount of waste rock drilled, moved, and processed. Improvements in drilling quality – the hole straightness, blast fragmentation, dilution, and ore loss, reduce the amount of waste rock which directly reduce CO2 emissions of the operation in total.

2 PRINCIPLES OF ROCKPULSE

The effectiveness of the drilling is traditionally measured with penetration rate and other measure-while-drilling (MWD) parameters. The challenge with these parameters is that they measure the rock response indirectly and with delay. A widely used parameter of Net Penetration Rate indicates productivity but cannot give information on how hard the drilling is for the rock drill and tools nor of the quality of the drilling – both key factors for efficiency and sustainability. Indirect and delayed measurement neither enable adjustment during drilling for improved results.

RockPulse is currently the only in situ measuring technique in the market enabling direct measurement of the stress waves in rock drilling. A rock drill includes a hydraulically controlled piston. When the piston hits a shank, a stress wave impulse that travels through the rod to the rock interface is created. From each impulse a reflection wave returns to the rock drill, providing valuable information on the drilling. The data provided by the RockPulse sensor, placed in the front of the rock drill, is accurate, live and measures a direct response from the rock.

The knowledge produced by the sensor has proven to be an effective way to adjust the drilling in challenging rock conditions such as fractured bedrock or varying rock hardness. With the measurement data, the driller gains detailed information of the bit-rock-contact and its quality. This helps to avoid under- or overfeed situations, which can cause breakages in the shanks, rods and bits as well as hole deviation.

It is common that in surface drilling the driller needs to first drill through a weathered bedrock. In the weathered-unweathered bedrock contact zone, the change in rock conditions can cause breakages in drill bits and rods. With the help of the sensor the driller can recognize the change instantly, enabling the adjustment of the drilling parameters in real-time. This increases the tool's lifetime and lowers the time needed for fishing tools from the hole after a breakage. This reduces also the risk of metal parts ending up in the crusher.

The information of the drilling produced by the RockPulse sensor is visualized into three new gauges (Figure 1).

2.1 Usage of the RockPulse gauges

The Drill Bit Response -gauge shows information of the bit-rock-contact. A good bit-rock-contact is prerequisite for effective rock breakage. If the contact is not good, the drilling is not efficient and causes additional stress on the tools. The gauge will also react in a situation where the bit is overly worn and in need of regrinding.

The Tools Load -gauge shows information of the amount of tensile stress waves that reflect to the rock drill. A high Tools Load value indicates high stress on the tools and the rock drill, which is a cause of unsuitable drilling settings or tools.

The Feed Level -gauge enables fine tuning the feed level to optimum, to fit the rock conditions. For example, when the drilling changes from soft to hard rock, the feed level needs to be raised so that the bit hits the rock with suitable force. Underfeed causes stress on the tools and lowers

penetration rate. On the other hand, when moving from hard rock to soft or entering a fracture zone, feed level needs to be lowered to avoid hole deviation caused by overfeed.

The RockPulse system has been proven to be especially beneficial for less experienced drillers who might not have enough knowledge of how the penetration rate, tool consumption and hole deviation can be balanced. The RockPulse system provides easy to use tools to follow and act on. More experienced drillers might use it periodically to adjust the drilling parameters when changing the location of the drill rig, when drilling in challenging rock conditions or for support in problem solving in different situations.

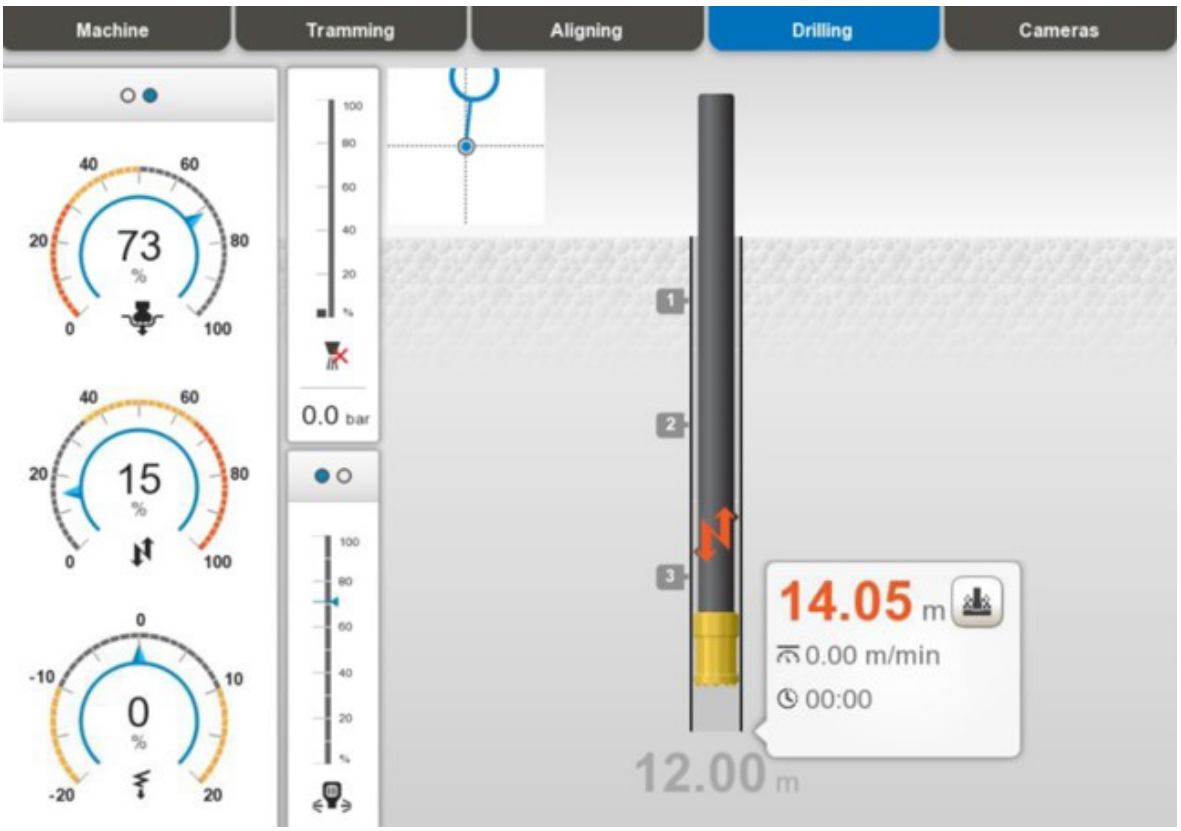

Figure 1. RockPulse-gauges in the rig's user interface. Drill Bit Response (up) shows bit-rock contact, Tools Load (middle) shows the amount of tensile stress and Feed Level (down) shows over- and underfeed situations.

3 SUCCESS STORY

The RockPulse system was tested in a field test together with a customer, who operates an open pit mine in vulcanic stone and varying rock conditions. One of the mine's Sandvik Pantera DP1100i machines was equipped with the RockPulse system for the first time. Installing the system requires a small update to the hardware and software of the machine, which in this case took five hours to complete. MWD data collection, as well as information of the tool consumption, had been started for the machine for a period time before installation of the RockPulse system, enabling decent comparison at the end of the field test.

Taking the RockPulse system into use lead to a drop in the shank consumption on the particular test machine by 60 %. In addition to that the consumption of rods dropped by 14 %. In this case, the reduction of pure steel in the form of shanks and rods adds up to more than 1.4 tons of material, which equals to 1.5 tons of CO2 emissions annually. Through continuous technological development, sourcing steel from steel producers with a lower carbon footprint, and the recycling of used non-regrindable tools, Sandvik Rock Tools has succeeded in reducing the CO2 emissions in produced ton

of shanks and rods to a value of 1.1 CO2 tons compared to the average of roughly 1.9 CO2 tons per steel tons (World Steel Association, 2021). The above mentioned 1.5 tons of CO2 compares to driving 12 500 km with a diesel car with fuel/CO2 rate of 0.12 kgCO2/km, which is the European average (European Environment Agency, 2020).

In addition to the savings in steel due to less consumption of tools, the system reduces fuel consumption. RockPulse contributes to not losing energy due to unsuitable pressure levels used for certain rock conditions. Optimally adjusted drilling parameters can increase the efficiency up to 5%, which equals to a reduction in fuel consumption of about three tons of CO2 emission annually per machine, equivalent to 25 000 km with a diesel car.

4 SUMMARY AND OUTLOOK

The effort it takes to excavate metals and minerals from bedrock and process them is high. The mineral resources left are also harder and harder to mine. It makes sense to put effort into drilling smart. RockPulse is a very potential method for saving the environment as it provides economical bonuses at the same time.

Utilizing the RockPulse system has a direct effect on fuel consumption as the same drilling results can often be achieved with lower pressure levels. The savings on tool consumption can be measured in tons per year per machine, which is significant. Adding RockPulse to a fleet of 10 drill rigs can reduce CO2 emissions for the amount equal to annual emissions of 375 000 km driving with diesel cars, considering savings on fuel and spare part consumption combined.

RockPulse's contribution to the overall quality of the drilling is difficult to quantify. Customers, however, report instant improvements in hole quality, due to precisely adjusted drilling settings in comparison to changes in the rock.

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