Improved Rock Drilling With Diarot Analysis

Simulation Assists Problem Solving

For over a decade, Atlas Copco experts have gathered data from mining, surface drilling and tunnelling projects all over the world. This information has been stored in Diarot, a rock drilling simulation program. Diarot is a unique system, which makes it possible to simulate rock drilling on a particular rig, and then evaluate the result. All without leaving the office! Diarot assists the customer in choosing the right parameters for his rig before the first hole is ever drilled. Likewise, if a problem occurs in the field, possibly because there has been a change in the geology of the rock to be drilled, Diarot can delineate the problem and identify the solution. Numerous case histories from different applications have been recorded where Diarot has come up with the right answer. Whether the drill bit is wrong for the rock, or the rock drill stroke is too long, or the hydraulic oil temperature is running too high, Diarot will analyze the problem and make recommendations to improve the entire rock drilling process. Diarot will always give an answer, and, if the customer input is correct, the answer will be correct.

Diarot will optimize drilling rates and drillsteel economy.

Introduction

Achieving the optimal performance from a drillrig involves practical testing to evaluate penetration rate, grinding intervals, service life and costs, to find the most efficient combination of components such as drill bits and drill strings.

Diarot contains a database, with information on each of Atlas Copco's rock drills and other components, as well as rock data from various areas throughout the world. The program takes into consideration all the parts contained in a system, including the rock drill, bits and drill steel, feed, hydraulic system, parameter settings, and the nature and condition of the rock.

Good drilling economy requires drill steel joints that are well tightened. A well-tightened joint is obtained through sufficient rotation resistance from the bit.

Friction losses in the hoses, the rotation motor, and the gear in the rock drill all contribute to the idling rotation pressure. The geometry of the drill steel threads, and the dimensions of the bit, demand a certain torque for joints to be well tightened, and this torque increases with the rotation speed. The torque in the drill steel is proportional to the rotation pressure increase from idling to drilling. The drillrig control system should accordingly be designed so that the thrust force is automatically adjusted to hold the rotation pressure at a predetermined value. When drilling in softer rock, the buttons penetrate deeper into the bottom of the hole, and a greater torque is required to rotate the drill steel, unless the thrust force is not reduced simultaneously. Diarot tells the user what rotation pressure should be applied to obtain well-tightened drill steel joints. It simply

Rocket Boomer L1 C-DH drillrig at Linwood Stone.

specifies the settings for percussion pressure, rotation speed, drill steel dimensions, thread geometry, and so on.

Unique Tool

Diarot is unique, with its library of gathered information, and the possibility to simulate the activity of a complete rig. For example, when projecting drillrig performance for a tunnel, or when designing equipment upgrades, it is possible to simulate drilling with a large number of different rock drills, as their characteristics are stored in the library. The settings of these rock drills can be fine-tuned, and tested, in order to arrive at the right results for a particular project. Likewise, different rock drills or drill strings can be tested for the same application in varying rock conditions, in order to adjust settings such as feed force, rotation speed, stroke position and impact pressure.

The expected drilling rates can be calculated, and the optimal setting of the system can be delineated. It can be decided whether new rock drills on old rigs will be an alternative, or whether it is better to buy new rigs. Diarot will also work out if different bit grinding intervals will make a difference to bit life.

Backward calculations using Diarot make it possible to determine the character of a rock, based on measured production results. That calculated rock quality can then be used to investigate the effect of changing other parameters, such as rock drill, percussion pressure, and stroke lengths.

When it comes to rock drilling, there are many factors governing the overall result, and all parts of the process must work smoothly. Diarot is a unique tool, in that it is possible to measure and control the entire process, before the first hole is even drilled!

Better performance

At a worksite close to Stockholm's Arlanda international airport, an Atlas Copco ROC 642HP drillrig was bench drilling 76 mm holes. The temperature on the coupling was 80 degrees C, and a Diarot simulation was carried out to evaluate different drill bits, with reference to the optimal settings of the COP 1838HE rock drill. Ballistic bits were tested, and proved to be the best, resulting in increased performance.

Going full-ballistic at Linwood. The new Secoroc button bit model -37-66, with longer button protrusion and improved flushing capacity, for increased penetration rate in soft rock.

The COP 1838HE rock drill being used has different stroke positions, as opposed to a conventional drill with a single fixed stroke length. Changing the stroke length gives an extra dimension in tuning the impact energy and frequency. In this case, position 3, with an impact pressure of 180 bar, had been used for drilling to date. The Diarot recommendation was to change to a shorter stroke, using position 2, with an impact pressure of 205 bar.

Different rotation speed and feed force settings were adjusted to the higher frequency produced by the rock drill, and the Diarot simulation also provided a full recommendation for all settings. The rock drill ran much more smoothly, and the coupling temperature halved, from around 80 degrees C to 40 degrees C.

The rig used 3.6 m-long T45 rods for drilling holes ranging between 6 m and 15 m deep, and the regrinding interval was some 50 m. After ten regrinds, it was difficult to maintain the ballistic profile of the buttons, and the customer re-sharpened them to a conventional spherical profile.

With the application of the new Diarot settings, wear on the threads was low, uncoupling the rods was easy, and the life of the Secoroc bits exceeded 1,200 m.

Weekly production increased from 1,400 m to an average of 1,700 m, with a best week of 1,820 m. Fuel consumption was low at 15 lit/hour, a figure which is less than half that of comparable rigs, and which saved more than a half litre of dieseline per drilled metre. At 40,000 m/year, the call to Diarot proved a great saver!

Improved Penetration

At Auersmacher in Germany, the Diarot program was used on a diesel-hydraulic single-boom Rocket Boomer L1 C-DH equipped with a COP 1838HF rock drill to establish the correct settings for the rig. Blast holes of 51 mm diameter are now being drilled to depths of 3.4 m in limestone at 6-8 m/min, a doubling of the previous standard performance. In this case, the optimum rotation speed was calculated to be 400 rev/min. Dropping it to 300 rev/min reduces the penetration rate by 2 m/min.

Another Rocket Boomer L1 C-DH was delivered to the Linwood Stone mine in Iowa, USA for use in limestone with an average compressive strength of 165 Mpa. This rig is equipped with RCS using ABC Basic software for assisted boom positioning, collaring point, hole direction, hole depth control, and statistics. The result was actually better than calculated, because of changing the rotation speed to 400+ rev/min and using a newly developed button bit from Atlas Copco Secoroc, with increased button protrusion, and more and bigger flushing holes.

The Rocket Boomer L1 C-DH is achieving penetration rates of 3.5 to 4.5 m/min, which is a doubling in output over the previous generation of drillrigs. The Diarot calculation was used to find the correct settings for the drillrig, without using trial and error.

At Mineradao Serra Da Fortaleza in Brazil, data was collected from a COP 1238ME rock drill mounted on a Simba H254. The Diarot calculation indicated that the regrinding interval should be reduced to once every two holes. The result was a penetration rate increase to 1.09 m/min from 0.99 m/min. As a bonus, shank life increased from 1,810 to 2,360 drilled metres and rod life increased from 450 to 580 drilled metres.

At Companhia Vale Do Rio Doce (CVRD) another COP 1238ME mounted on a Simba H254 was studied, resulting in a recommendation being made to decrease the regrinding interval to one hole. Penetration rate was increased from 0.99 m/min to 1.28 m/min. Shank life also increased from 1,420 drilled metres to 2,450 drilled metres and rod life from 310 drilled metres to 530 drilled metres.

In both of these cases, the bits were being over-drilled, with large risk of button breakage, which can lead to a reduction of the average drill bit life.

In all cases, not only the impact pressure had to be changed, but also the feed pressure and the rotation speed. It is very important to change all settings according to the calculations, in order to achieve the forecast result.

The measuring of the coupling temperature during drilling is also important. The worst condition exists just before regrinding the bit, at the time when it generates the lowest torque. If the torque becomes too low, then the wear of the threads will increase, since the joint runs open, with a reduction of drill steel life as a consequence.

Bit Life

Consumption of drill bits forms a significant part of the costs of blast hole drilling in construction and mining. During drilling, the cemented carbide buttons, or inserts, wear flat. When drilling is carried out with constant percussion pressure, the drilling rate decreases with increasing wear flat. If the drilling continues long enough without regrinding, then the drilling rate finally becomes zero. This occurs earlier for bigger drill bits, and for harder rock.

The drilling rate and the wear flat increase are linked, and determined by several input data, such as piston mass, percussion pressure, drill steel rotation rate, thrust force, drill steel dimensions, bit diameter, number of buttons and button size, button wear resistance, flushing medium, and rock hardness and abrasivity.

The ideal temperature on the coupling should be down to 60°C for air flushing and 45°C for water flushing.

For example, water flushing provides better cooling and less wear flat than air flushing. However, when the bit penetrates the bottom of the hole with about the same velocity as the impact velocity of the piston, which is about 10 m/s, significant energy is required to push away the water in front of the bit. This results in a reduced drilling rate in comparison with air flushing.

The Diarot computer program uses physical models for most factors that determine the drilling rate and the wear flat increase of the bit, and the drilling economy. For the remainder, empirical relations are used in terms of analytical mathematical equations. The constants in these empirical relations are always non-dimensional, and are obtained by comparing calculated values with measured ones from many real drilling operations of widely different character.

Snakeskin

The Diarot program allows the user to calculate the stress on the bit that leads to fatigue, or breakage of the buttons or inserts.

Drilling in certain rock, such as limestone and marble, causes negligible wear to the bit. The buttons are heated by the friction, and cooled by the flushing medium.

This results in micro-cracking in the cemented carbide button surfaces. When these cracks are not continuously removed by abrasive wear, they grow into the cemented carbide, and eventually become visible as snakeskin. If such snakeskin is not regularly removed by regrinding, then the buttons will eventually fall apart, or be crushed.

Diarot does not allow longer regrinding intervals than 400 m. If the input data indicate a greater regrinding interval than 400 m, then the program adjusts the value of the regrinding wear flat to below 400 m. The output data indicates that 0.5 mm is ground off the buttons to eliminate snake skin, and that the number of possible regrindings is calculated accordingly.

The total cost for the bit, including regrinding, is of utmost interest for the

INPUT DATA

Project	LINWOOD DAVENPORT IOWA LINWOOD1838HF		
File name	Linwood1838HF.DAT		
Application	DRIFTING		
Rig	R.BOOMER L1 C-DH		
Feed	BMH 6316		
Rock drill	COP 1838HF-R38H35 05		
Stroke length position			
Percussion pressure		MPa	22,5
Rotation motor			OMS 100
Oil temperature		°C	40
Oil viscosity at 40°C		cSt	46
Rock designation			LIMESTONE
location			LINWOOD IOWA USA
compressive strength		MPa	165
stamp strength		MPa	1650
brittleness			1,15
indexation parameter		mm	8,10
Cherchar Abrasivity Index			2,00
density		kg/m^3	2700
Hole depth		m	5,1
Drilling direction (>0° is upwards)		°	0
Drill steel	designation		R38H35
	length	m	5,40
	male/female		No
Bit diameter		mm	51
insert type			ballistic button
number of buttons			9
number of periphery buttons			6
periphery button diameter		mm	10,0
RETRAC			N
Rock-bit friction coefficient			0,20
Regrinding wear flat		mm	5,0
Flushing medium			Air

OUTPUT DATA

Project	LINWOOD DAVENPORT IOWA LINWOOD1838HF			
File name	Linwood1838HF.DAT			
Application	DRIFTING			
Percussion pressure	MPa	22,5		
Impact frequency	Hz	69		
Relative drill stress	%	91		
Number of regrindings		2		
Diameter wear after 2 regrindings	mm	1,7		
Recommended air flushing flow	l/sec	18		
		Optimum	Reduced	
Rotation rate	rpm	256	205	154
Accumulated drilling rate	m/min	3,62	3,53	3,26
Regrinding interval	m	1109	1172	1260
Bit service life	m	3326	3516	3779
Shank service life	m	6 990		
Coupling service life	m	4 890		
Rod service life	m	4 040		

Selected diarot input and output data for COP 1838HF.

customer. If the penetration rate drops, the drill steel and the shank life decreases, and excessive vibration and wear results on the drillrig.

Diarot in Tunnels

The Diarot expert program is available to owners of tunnelling drillrigs. All that is required is for the customer to provide reliable drilling information to his Atlas Copco service engineer. Details are needed of parameters, such as percussion pressure, rotation rate, and the corresponding accumulated drilling rate, plus the wear flat on the drill bit insert or button after one regrinding interval. The service engineer will send the information to a Diarot specialist for analysis.

He will start with a reverse Diarot calculation to determine relevant rock data, which is then used to work out the most effective drilling rates for other settings, situations and equipment. The results are presented to the customer, and, once the recommendations are implemented, the Diarot specialist will monitor the feedback. All communications can be via the Internet.

In the Diarot system, calculation of the total performance of drillrig, feed, control system, rock drill, drill steel and drill bit supports the concept of Total Rock Drilling Technology.

At the Viiki Extension Project in Helsinki, Finland, contractor YIT compared the performance of a COP 1838ME rock drill with the new COP 1838HF.

Diarot calculations predicted a 20% increase in performance. Practical drilling at the site with both rock drills produced the following penetration rates for a 51 mm bit with ballistic buttons: COP 1838ME 1.85 m/min; COP 1838HF 2.33 m/min. In both cases the “relative drill stress” was on the same level. Parameters such as impact pressure, feed pressure, and rotation speed were set according to the Diarot calculations. The HF version was the clear winner, with a 26% higher penetration rate than its rival, the ME.

by Åke Eklöf