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ABOUT THE ISSUE OF DETERMINATION OF SOLID ROCKS POSITION IN THE COAL BED'S TOP WALL IN LIGNITE QUARRIES USING DRILLING WORKS

1. INTRODUCTION

Overburden mining in lignite quarries has to deal – among other difficulties – with the occurrence of rocky grounds. The mining and exploration of these rocks requires increased costs and implementation of special technologies. These rocks' solidity under common pressure often amounts to 110 MPa (50–110 MPa) and thus radically exceeds ordinary 1–12,5 MPa. In case of higher accumulations in the movement of the bucket wheel excavator, these rocks cause abnormal abrasion of the mining part of the machine. In the quarry Bílina, for example, rocky grounds occur in 4 basic types. These rocks are coherent or incoherent bodies of various shapes, thicknesses, sizes, and types of placement. These various types of solid rocks are bound to different geological structures and types of mother soils, because they originate from various periods of diagenesis of overburden soils – clays and sands (Mach, 2003). Actual experiments using geophysical methods of occurrence examination of these solid rock positions have not brought expected and necessary results there. Their accuracy decreases rapidly with the depth of the position of the sought object. The majority of them have proven to be lowly effective in the conditions of the quarry Bílina. Too high costs connected with the efficiency comparable to drilling exploration also play an important role there. The failure of application of geophysical methods (caused by their inaccuracy, small depth range, and problematic implementation in the conditions of the mine Bílina) proves that one of possible solutions, which would credibly specify the range and placement of solid sandstone bodies, is the utilization of drilling exploration in a condensed boring network suitably chosen for this purpose.

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2. SUMMARY OF THE PRESENT KNOWLEDGE GAINED FROM THE DRILLING EXPLORATION'S IMPLEMENTATION IN THE MINE BÍLINA

The pieces of knowledge gained from the implementation of the drilling and geophysical explorations in the mine Bílina up to now can be summarized as follows:

- all the geophysical methods applied in the mine Bílina so far (seismic and radar methods) have not offered satisfactory information concerning the position of solid rocks in the coal bed's top wall; in case that no significant change comes in this aspect, drilling works will remain the only method ensuring objective information about the occurrence of solid rock positions – currently, with regard to the applied drilling technology and technical means, this method is demanding as far as time and costs are concerned;
- the currently used density of the boring network is lowly efficient in case of the occurrence of smaller objects;
- the application of logging methods has not brought satisfactory results (with regard to the fact that the occurrence of some sandstone rock positions is hardly interpretable), especially because of their low geophysical divergence from claystones;
- core drilling applied in the area is time consuming and thus uneconomic; this technology provides more exact data about the rock environment that is being drilled through in comparison with full-profile (coreless) drilling, however it is not necessary for the purpose, for which mines are working in this locality, i.e. finding and determining solid rock positions in the coal bed's top wall;
- the technology of full-profile rotary drilling with air laxage used so far, which is much cheaper in comparison to core drilling, is limited as far as depth is concerned (an unsuitable drilling outfit with a small depth range), a serious complication is an imperfect elevation of the rock detritus by air, especially in cases when water is present in the borehole;
- rotary drilling applying drill bits gets extremely expensive when drilling through solid rock positions, namely dolomitic sandstones, whose high abrasivity causes a considerable abrasion of the drilling tool's cutting elements, which, together with a substantially high solidity of these rocks under common pressure, decelerates or even completely stops the drilling process;
- the implementation of positive wells for explosive works and for the desintegration of solid rock positions for the following separate mining represents a considerable element of the complex of works carried out currently in the mine Bílina.

3. DELIMITATION OF FACTORS OF GEOLOGICAL CHARACTER LIMITING THE IMPLEMENTATION OF BORING EXPLORATION WORKS WHEN CHECKING THE OCCURRENCE OF SOLID ROCK POSITIONS

Complicated geological conditions in the coal bed's top wall belong to most serious factors, which significantly limit the possibilities of utilization of some, otherwise commonly used technologies of exploration wells' realization. The main limiting factors are as follows:

– the occurrence of rocks, whose solidity under common pressure is considerably variable, and sometimes amounts even to 110 MPa; particularly frequently occurring irregular tabular to lenticular bodies of mediumly to roughly granular, highly abrasive sandstone with dolomitic cement with a variable thickness, and a surface and depth placing (their spatial distribution in strongly deformed delta-shaped bodies is complicated) are a limiting factor for the choice of the drilling technology from the viewpoint of an effective desintegration of these rocks. Recently used drilling technologies, which have not been very successful when drilling through these solid rock positions, have to be replaced by new technologies with a disposition of managing the desintegration process in these rock types successfully. **The rotary-percussion drilling technology** using a downhole drill hammer appears to be very suitable there. This hammer type is able to keep the required output parameters even in higher depths in comparison with a surface rotary-percussion hammer;
– **a complicated geological structure of the coal bed's top wall**, where solid rock positions alternate with rocks with low solidity under common pressure, eventually where little consolidated and unstable rocks occur, can be problematic even for the downhole drill hammer from the viewpoint of its efficiency during the desintegration of rocks, particularly of soft and little consolidated ones. In these softer rock types, it may thus be more useful to carry out the rocks' desintegration in a classical rotary way with an implementation of cutting or rolling drilling tools combined with an effective laxage system than to use the downhole drill hammer. **The possibility of combining both technologies in the course of drilling, utilizing one, multifunctional drilling outfit, could help increase the drilling works' efficiency** not only in this, but also in other mining localities in the North Bohemian lignite basin, where drilling exploration works in the coal beds' top wall and intermediated layers are carried out;
– a very complicated geological structure of the coal bed's top wall – a complicated system of delta-shaped sabulous bodies and sabulous fillings of primeval river-basins (coarse-grained sand to fine-grained gravel) constitutes a considerable problem when realizing drilling works, in the course of which we can suppose a decreased stability of the well's walls, which, apart from repeated well shaft's cave-ins, brings about a worsened elevation of the rock detritus as a result of formation of caverns;
– **the presence of water**, which commonly occurs in the area, **in the borehole** limits the implementation of the drilling technology using air laxage, whose elevating power decreases with the increasing depth of the borehole; this problem can partly be solved by applying a more efficient compressor in comparison to commonly used existing types, or by the implementation of the drilling technology using water laxage (rather used in combination with classical, rotary drilling, eventually when applying rotary-percussion drilling with a surface hydraulic hammer). It is also possible to use the combination of rotary-percussion drilling by a downhole drill hammer with foam laxage, because foam, unlike air, keeps its elevating power when water-bearing horizons are drilled into (in local conditions, some companies use e.g. a polymerized foam MODIFOAM 735 by a Dutch concern Best Drilling Chemicals – BDC); in this case, **high operation costs** again constitute a limiting factor influencing the implementation of this drilling technology;

– with regard to **the necessity of gaining geological information at least in a two-year advance**, and with regard to the aggregate thickness of the height and depth profile of the overburden excavator, to meet this requirement it is necessary to choose a suitable quarry drilling outfit (utilizable for the rotary-percussion drilling technology, eventually capable of applying the combined way of drilling – rotary-percussion and rotary one) with a depth range at least 50 m, equipped with such a measuring technique which would be monitoring, recording, and evaluating the parameters of the drilling process essential for an accurate indication of solid rock positions in the coal bed's top wall. In doing so, it is necessary to bear in mind that the efficiency of the drilling process depends on many factors, which directly influence the characterizing magnitude of the rocks' disintegration – its drillability. This magnitude, representing the interaction machine (drilling tool) – rock, is dependent on a set of entering magnitudes, i.e. geological, technical, technological factors (desintegration's mode parameters), and other influences (massif's tension state, humidity, etc.). When the drilling outfit is not fully automated, the human factor enters the desintegration process, having a chance to partially or completely regulate the mode parameters with a bigger or smaller error (Jurman, Škvareková, 2004).

4. PROPOSING THE MOST SUITABLE METHOD DETERMINING SOLID AND VERY SOLID ROCK POSITIONS IN THE MINE BÍLINA

One of the crucial moments of every successful and effective project in quarry mining is selecting optimal machinery. The principal requirement is always the reliability and resistivity of the device when operating under difficult and demanding conditions. Other fundamental requirements are: universality, manoeuvrability, simple controllability, undemanding maintenance, and minimum service. Apart from the afore-mentioned criteria, under the drilling conditions of the coal bed's top wall in the mine Bílina, it is necessary to meet the following requirements:

– the drilling outfit's depth range – 50 m;
– the drilling outfit has to be equipped with measuring devices capable of registering the parameters necessary for the determination of solid rock positions in the coal bed's top wall.

For the reasons mentioned above, a new, more suitable drilling outfit has been chosen, which is supposed to reduce the afore-mentioned negative aspects of the existing method of the prediction of solid and very solid rock positions in the mine Bílina.

From the spectrum of examined and identified types of drilling outfits, **BPI Titon 300 R** appeared to be the most suitable for the above-mentioned application. This drilling outfit is manufactured by BPI Zeltweg (Austria), and imported into the Czech Republic by Rocktech. It is used in combination with the monitoring device Track, which determines the borehole position (depth and thickness) of the object with an excessive solidity under pressure by means of scanning and saving the drilling outfit's operating data. The saved data can be extracted within an arbitrary time interval and subsequently processed as necessary. This

combination of the BPI Titon 300 R drilling outfit with the monitoring device Track appears to be suitable for the determination of solid and very solid rock positions on the basis of monitoring the drilling process. This monitoring device evaluates the following measured operating parameters:

- depth + advancement's velocity,
- drilling moment + rotation,
- weight on the bit and draw,
- air pressure.

The introduced parameters saved on MMC memory cards can subsequently be displayed both in a numeric and graphic form (displaying the rate of the selected parameter in dependence on the depth).

When choosing a suitable rotary-percussion drilling method type, the downhole drill hammer was preferred to the surface one.

5. VERIFICATION OF THE PROPOSED METHODOLOGY IN PRACTICE

The proposed drilling outfit, including the monitoring device Track, was recommended by the decision-making team of VŠB-TU Ostrava for functional testing when determining solid and very solid rock positions before the actual introduction into operation. After having consulted SD a.s. Chomutov, who carry out the exploratory drilling works, for the verification of coreless drilling, the drilling outfit Böhler TCD 221 was used, which makes it possible to drill in both rotary and rotary-percussion way in combination with the downhole drill hammer, supplemented by the evaluation device Track by PARTNER mb s.r.o., whose parameters are similar to those of the primarily proposed drilling outfit – Titon type.

In 2007, 40 wells in a depth range from c. 8,7 m to 36,0 m with prevailing depths c. 30 m were drilled in this locality in total. The total wells' length amounted to 1046,1 m. These wells of the verification phase were drilled in a full-profile, rotary way with a possibility of switching to rotary-percussion drilling when reaching solid or very solid rock positions. Drill bits, specially designed for the purpose in SD a.s. Chomutov, were used for rotary drilling.

For evaluation, the graphic documentation in a form of a column record in a coordinate system x-y was used, which takes into account the dependence: measured variable (parameter) – depth. It enables a simultaneous monitoring of these basic parameters characterizing the drilling process, and their changes in the course of drilling:

- weight on the drilling tool [kN],
- advancement (drilling pace) [$m \cdot h^{-1}$],
- revolutions [rev. min^{-1}],
- drilling (torsion) moment [kN·m],
- energy [$kJ \cdot m^{-3}$],
- pressure [MPa]
- flow volume [$l \cdot min^{-1}$], eventually [$l \cdot s^{-1}$],
- grippers [–],
- flushing [–].

For the determination of boreholes' sections with very solid or solid positions in overburden rocks, the curves representing the progression of 4 parameters listed below can be considered as crucial and best utilizable:

- weight on the drilling tool,
- advancement (drilling pace),
- drilling (torsion) moment [kN·m],
- energy.

Other measured parameters in this evaluation works' phase can be considered as just supplementary and utilizable mostly for the purpose of specification of the information about the drilling's progression.

- Advancement (drilling pace):
  - The rocks' solidity characteristics' examination gained on the basis of the evaluation of graphic records of the drilling pace's progression is feasible, however in case that the drilling outfit's operating staff modifies the entering parameters of the drilling mode (weight, revolutions) when the drilled-through rocks change, in order to drill through more solid rocks while keeping relatively high drilling speeds, the acquired data can be considered as rather approximate, utilizable for the drilled solid rock positions' determination, however not in absolute rates, but just in relative ones. For the purposes of evaluation, keeping the constant rate of entered parameters appears to be the more suitable option, which would enable a more accurate mutual comparision of the drilled solid rock positions, in case of both one well and more wells within the exploratory network.
- Weight on the bit (entering parameter):
  - This parameter can be regulated by the drilling outfit's operating staff, these adjustments influence the evaluation works' qualitative aspect. The parameter's change affects not only the drilling pace's rates' change, but also the progression of curves representing the moment and energy rates.
- Drilling (torsion) moment (final parameter)
  - The curve representing this parameter's progression has a similar rates' progression as the curve representing the entering parameter's rate – weight on the drilling tool. This trend is evident in the records, where a more particular scale's range was used. For a more detailed evaluation of the influence of drilling mode parameters' changes and differently drillable rocks' changes on the progression of the curve representing this parameter, a long-term monitoring of the drilling process right at the drilling outfit is necessary.
- Energy (final parameter)
  - The progression of the curve representing energy rates has a similar character as the weight's curve, and in case of a more detailed data reading, as the moment's curve. As regards the interpretation and evaluation of this record, to get a more detailed and exact idea about the correlation between the progression of the curve representing

energy rates and the actual rock's desintegration process by drilling, it is necessary to carry out a more detailed analysis of operations realized at the drilling outfit, including a long-term monitoring of the drilling shaft's activity in the borehole (vibrations, the smoothness of the drilling shaft's advancement in the borehole, the drilling string centring, etc.).

6. FINAL SUMMARY OF KNOWLEDGE GAINED FROM THE VERIFICATION PHASE OF DRILLING WORKS

In the course of this phase of the verification of the proposed methodology determining solid and very solid rock positions in the coal bed's top wall in the mine Bílina, all 40 wells were drilled using the rotary full-profile drilling technology. With regard to the drilled-through rocks' solidity character, in which more solid, but through rotary full-profile drilling 'feasible' rock positions of hardly drillable rocks sporadically occured, it was not necessary to implement the rotary-percussion hammer technology. These more solid rocks' positions were thus drilled through in a rotary way within the current setting of mode parameters, especially the weight on the drilling tool. In case of thick, very solid rock positions in the coal bed's top wall, where the rotary full-profile drilling technology would not be successful, it would be necessary to implement the downhole drill hammer. The proposed drilling outfit proved efficient in the course of its implementation in this verification works' phase, and in combination with the installed monitoring device Track it appears to be suitable for the following phases of drilling works.

On the basis of knowledge gained by the study of the graphic documentation, it can be stated that:

- the determination of solid rock positions in the coal bed's overburden rocks on the basis of the analysis of the graphic record, and with the utilization of the digital record of data from the course of drilling of full-profile wells in the rotary way is **feasible**;
- it can be assumed that even in case of the application of rotary-percussion drilling with the utilization of the downhole drill hammer in intervals, which will not be drillable in the rotary way, the proposed methodology determining solid and very solid rock positions will be **utilizable**, the character of the curve representing the progression of rates of individual monitored parameters will be substantially different in these record's intervals;
- the knowledge mentioned here was gained on the basis of the study and examination of the graphic documentation from 40 wells. This evaluation works' phase can be considered as the beginning of the search for the optimum way of solving the problems connected with the determination of solid rock positions with the utilization of the graphic and numeric documentation gained when drilling full-profile wells in the mine Bílina.

Czech – English translation: Bc. et Bc. Jiří Mazáč

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