Evaluation of Roof Bolting Requirements Based on In-Mine Roof Bolter Drilling

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ABSTRACT

A new mechanical approach to estimate rock strengths using the acquired drilling parameters has been proposed. This approach takes a number of important factors, that have never been studied in the previous researches, into the considerations. Good results have been shown using the new approach on the testing data.

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RESEARCH OBJECTIVES

Roof bolting is the most popular method for underground openings in the mining industry, especially in the bedded deposits such as coal, potash, salt etc. In fact, all U.S. underground coal mine entries are roof-bolted as required by law.

However, roof falls still occur frequently in the roof bolted entries. The two possible reasons are: the lack of knowledge of and technology to detect the roof geological conditions in advance of mining, and lack of roof bolting design criteria for modern roof bolting systems.

This research is to develop a method for predicting the roof geology and stability condition in real time during roof bolting operation. Based on such information, roof bolting design criteria for modern roof bolting systems will be developed for implementation in real time.

For the prediction of roof geology and stability condition in real time, a micro-processor will be used and a program (ROOFSTAB) developed to monitor the drilling parameters. These parameters include thrust, penetration rate, rotation torque, rotation rate, drill position, and vacuum condition. At the same time, rock cores will be obtained a borehole drilled immediate next to bolt hole for the determination of the mechanical properties and structure of the rock strata within the bolting horizon. A relationship or relationships will be established between these drilling parameters and the mechanical and structural data of the roof strata. A roof bolter control system will be developed to monitor these drill parameters. For the development of ROOFSTAB drilling parameters will be obtained from four different coal seams in four mine sites. With this information, a computer program will be developed for use in conjunction with the roof bolter for real-time prediction of strata mechanical properties and structures in roof strata within the bolting horizon.

For the development of roof bolting design criteria, numerical simulations will be performed to investigate the mechanisms of modern roof bolting systems including both the tension and non-tensioned (or fully grouted) bolts. Parameters to be studied are: bolt size/strength, bolt length, bolt spacing, grout annulus and length, and roof geology (massive strata, fractured, and laminated or thinly-bedded). The results of these experiments will be analyzed to develop a roof bolting criterion or criteria program (ROOFBOLT) that will be combined with the ROOFSTAB for use in conjunction with roof bolt installation.

The following main tasks are to be performed for achieving the proposed research objectives:

- A. Development of Operator Control Technology for Monitoring Roof Bolter Drill Operations Parameters.
- B. Laboratory and Underground Testing.
- C. Drill Parameters Data Analysis and Correlation with Roof Stability Conditions
Software Development for Mapping of Roof Geological Conditions
- D. Laboratory Tests to Investigate the Mechanisms of Roof Bolting Using Simulated Materials
- E. Development of Roof Bolting Design Criteria for Implementation in Primary Roof Bolting Cycle

EXPERIMENTAL

A systematic approach has been proposed in the acquisition and analysis of the drilling data. In this approach, the performance of the drilling operation is considered to be dependent on the three sub-systems: (1) drill power supplies, (2) drill bit and its geometry, and (3) the rock strata to be drilled as shown in Fig. 1. The determination of the characteristics of sub-system 3 is the most important objective of this research. The characterization of the rock strata depends on a well understanding of sub-systems 1 and 2. In order to understand the drill power supply system, two more sensors have been added on the research roof bolter unit to monitor the flow rates of the hydraulic fluids provided to the thrust cylinder and torque motor. Using the data obtained from these two sensors, the powers supplied for generating the required thrust and torque in the drilling operation can be determined. The sensors have been installed and the monitoring unit has been re-programmed to reflect such change. In addition to the tests performed on solid concrete block and simulated fracture block in this reporting period, a set of tests has been performed on the solid concrete block with the new added sensors on the research roof bolter at the end of this reporting period.

Fig. 1 Schematic of the System Approach for Drilling Data Interpretation

RESULTS AND DISCUSSION

The objective of this research project is to develop the methodology for evaluating the geology and stability condition of the roof strata of underground openings in real-time during roof bolting operation. Based on such information, bolting requirements for modern roof bolting systems will be developed for implementation in real time. The following main items of works performed in this reporting period are listed:

1. New Research Approach in Characterizing the Rock Strata

The characterization of the rock strata includes the following three main tasks: (1) determining strengths of the rock layers, (2) locating the layer interfaces, and (3) determining the sizes and locations of the fractures/voids in the roof rock strata. The research works for each of the main tasks are detailed.

For the main task 1, an analytical method has been proposed for determining the rock strengths. It has been found from the collected and derived drilling parameters that there exist good linear relationships between the thrust or torque and the bite depth (i.e., penetration per rotation) as shown in Fig. 2. The geometries of the drill bits used in the drilling tests have also been studied. Using the geometrical information of the drill bits and the relationships between thrust/torque and bite depth, the compressive and shear strength of the rock can be determined. This method is still in the development stage but it has shown a very promising sign.

Fig. 2 Relationship Between Drilling Thrust and Bite Depth

In locating the interfaces of the rock layers, the rotational acceleration rate seems to be the most promising parameter at this time.

In the task of determining the sizes and locations of the fractures and voids, a concrete block simulating the fractures or voids has been constructed. Three sizes of the fractures, 1/16", 1/8" and 3/8" have been built in the block. The tests performed on the simulated fracture block showed that the locations of all the simulated fractures can be consistently determined using the distribution patterns of the thrust. However, more work is needed for determining the sizes of the fractures.

2. Exploring the Roof Bolting Mechanisms

In exploring the mechanisms involved in roof bolting, continued efforts have been made to use the finite element (FE) modeling techniques. had been performed to study the supporting mechanisms using the tensioned bolts and the full grouted risen bolts. These FE models had been built as close to the reality as possible by considering the bedding planes, in-situ horizontal stress field, the bolt-rock interactions and various bolt sizes, lengths and installation conditions. The preliminary results from the tensioned bolt FE simulations during the entry development had been summarized in a technical paper (Zhang and Peng, 2001) to be published in the proceedings of the 20th International Conference on Ground Control in Mining. The presence of bedding planes in the roof strata not only changes the distribution of the stress field in the roof but also significantly increases the roof deflections. The pre-tension applied on the mechanically anchored roof bolts can reduce the possibility and the amount of sliding and separation along the bedding planes – the direct causes for roof falls. For the fully grouted risen bolts, by increasing the bolt diameter and using higher adhesive risen could also reduce the bed separation and roof deflection. More FE simulations will be conducted under various mining, geological and geo-mechanical conditions. The results from these simulations will be used to develop the criteria for roof bolting design.

3. Development of On-Board Data Visualization and Database Program

The development of a computer program to display the original and derived drilling parameters, the identified rock types and geological structures in the bolting horizon in 2-D and 3-D has been started in this quarter. A database is also to be included in this program. The program will be installed on the computer on-board of the roof bolter.

Progress on Planned Tasks

Tasks Planned in the Proposal	Progress
A. Development of Operator Control Technology for Monitoring Roof Bolter Drill Operation Parameters	As detailed in item No. 1
B. Laboratory and Underground Testing	None
C. Drill Parameter Data Analysis and Correlation with Roof Stability Conditions	As detailed in item No. 2
D. Software Development for Mapping of Roof Geological Conditions	As detailed in item No. 4
E. Computer Modeling to Investigate the Mechanisms of Roof Bolting	As detailed in item No. 3
F. Development of Roof Bolting Design Requirements for Implementation in the Primary Roof Bolting Cycle	None

CONCLUSIONS

A new mechanical approach to estimate rock strengths using the acquired drilling parameters has been proposed. This approach takes a number of important factors, that have never been studied in the previous researches, into the considerations. Good results have been shown using the new approach on the testing data.

REFERENCE

Zhang, Y.Q., and S.S. Peng, 2001, "Effects of Bedding Plane Sliding and Separation on Tensioned Bolt in Layered Rood," *Proc. 20th International Conference on Ground Control in Mining*, Ed. S.S. Peng and C. Mark, West Virginia University, Morgantown, WV, Aug. 7 – 9, 2000, pp. 226-234.