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

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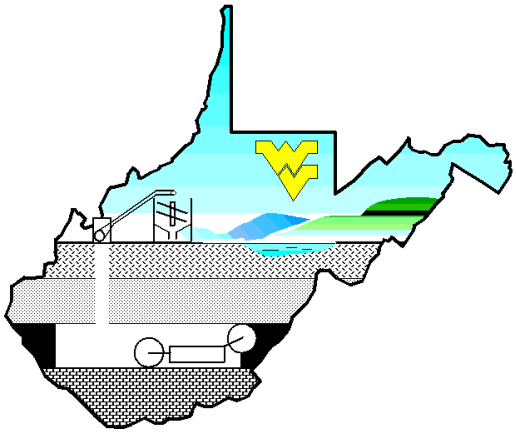

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ABSTRACT

In this quarter, retrofitting work to build a dedicated roof bolter for this research has been started. A number of numerical methods have been developed to improve the quality of and to analyze the collected drilling parameters. Finite element modeling of roof bolting mechanism is continuing.

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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 microprocessor 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

No laboratory or field drilling tests was performed in this quarter. However, the retrofitting of a roof bolter to a dedicated unit for this research involves many calibration testings.

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. Improvement of the Feedback Control System

A large amount of drilling data has been collected in laboratory and field conditions using the feedback control system developed by the J.H. Fletcher & Company. During the analysis of the collected drilling data performed in the first quarter of 2001, it was found that certain improvements should be made to the feedback control system. During the second quarter of 2001 or this reporting period, the J.H. Fletcher & Company was working on improving the feedback control system and retrofitting a roof bolter dedicated to this research project with new hydraulic system and sensors for this research. The total expenditure in this reporting period for retrofitting the dedicated roof bolter by the J.H. Fletcher & Company was $46,526.50. The work on this dedicated machine had not been completed yet.

2. Data Processing and Analysis

In processing and analyzing the collected drilling data, a number of new numerical techniques had been employed to process the raw data. The supervised multivariate discriminant analysis method had been used to classify the rock types. It was found that a number of the original and derived drilling parameters could be used to classify the rock types and to locate the rock interfaces and fractures. These important original parameters are thrust, penetration and rotational rates, torque and penetration per revolution. The derived parameters are the penetration and rotational accelerations, specific energy, and power consumed by torque. Through processing the collected drilling data, the needed improvements on the feedback control system had been identified.

3. Exploring the Roof Bolting Mechanisms

Although roof bolting has been a common practice in US underground mines after World War II, the mechanisms for the roof bolts to support the roof strata of the underground openings in layered structures have not been quantitatively understood. Due to the fast development in computer hardware and software in recent years, it becomes possible now to investigate the roof bolting mechanisms more realistically using numerical analysis techniques. During this reporting period, two types of 3-D finite element (FE) modeling 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.

4. 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

Development of a dedicated roof bolter to avoid the variations in machine performance characteristics is under way in this quarter. The proposed data processing methods have improved the quality and usefulness of the collected drilling data. The developed numerical simulation models are capable of considering the effects of bedding plane sliding and separation in the bolting horizon, a very common issue.

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.