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

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Quarterly Technical Progress Report

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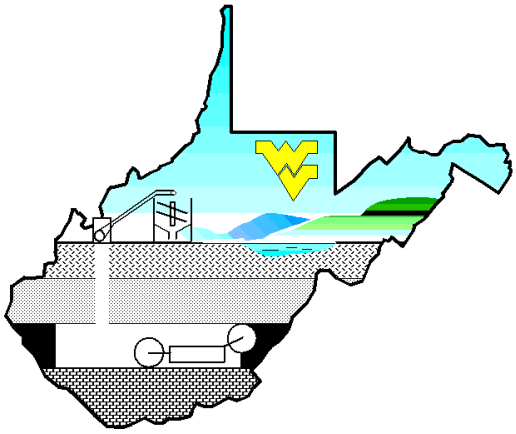

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DISCLAIMER

ABSTRACT

More laboratory tests have been performed in this quarter. The analysis performed on the testing data showed: (1) abnormal rotational accelerations can be used as the indicator of the rock interfaces, and (2) the sharp drops of drilling thrust and torque agree well with the locations of fractures.

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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

In order to avoid inconsistency problems in the drilling data, a used roof bolter has been retrofitted by the J.H. Fletcher & Co so that it can be dedicated for the research project. The roof bolter is ready for underground field testing by the end of this quarter. Using the dedicated roof bolter, laboratory tests have been performed on two new concrete blocks with different embedded rock layers.

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. 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.

Development of the systematic and mechanics-based approach for interpreting the drilling parameters is continuing. Based on this approach, methods for determining the rock compressive and shear strengths taking into considerations of the geometry of the drill bit and the rock failure mechanisms in rotary drilling have been developed. Therefore, the bit wear process, an important factor in drilling operation, can be considered. This approach has been proven, by the laboratory tests, to be more consistent and versatile than those methods based on the concept of specific energy.

It is also found that the interfaces of rock layers could be detected by using the rotational acceleration (Fig. 1) while the locations of the fractures/voids can be determined by thrust distribution patterns (Fig. 2). However, the sizes of the fractures/voids can not be determined at this stage.

A technical paper presenting the latest developments in this research titled as "Identification of Lithologic Changes Using Drilling Parameters" has been presented at the 2002 SME annual meeting on Feb. 26 in Phoenix, AZ

2. Exploring the Roof Bolting Mechanisms

In exploring the mechanisms involved in roof bolting, continued efforts have been made to apply the finite element (FE) modeling techniques for the studies of the support-

ing 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. Three-Dimensional finite element models for simulating the tensioned bolt have been developed. Two-Dimensional finite element models for simulating the fully grouted resin bolts have also been developed. The effects of sliding and separation of bedding planes have been considered in these models.

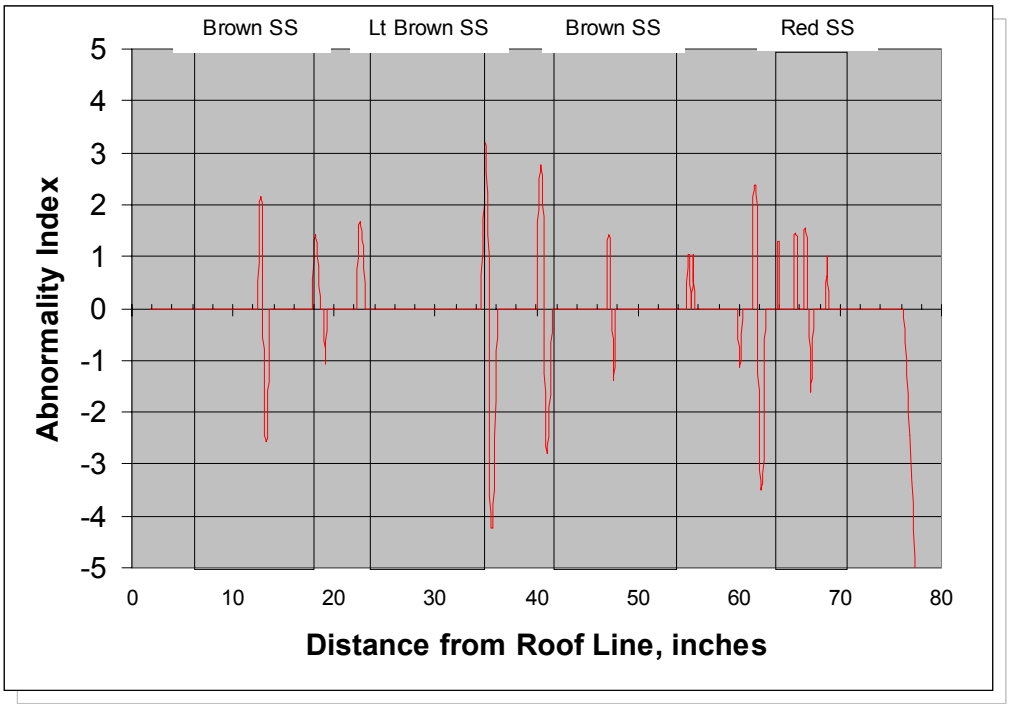

Fig. 1 Correlation Between Locations of Rock Interface and Abnormal Points in Rotational Acceleration

Based on the numerical modeling results, the design criteria for tensioned and fully grouted resin bolts are being developed. The yielding zone developed over the entry can be used to determine the bolt length, the magnitude of plastic strain can be used to judge the roof local stability, and the stress distribution around the entry and bolt load are also used to check roof stability.

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. The program will be installed on the computer on-board of the roof bolter

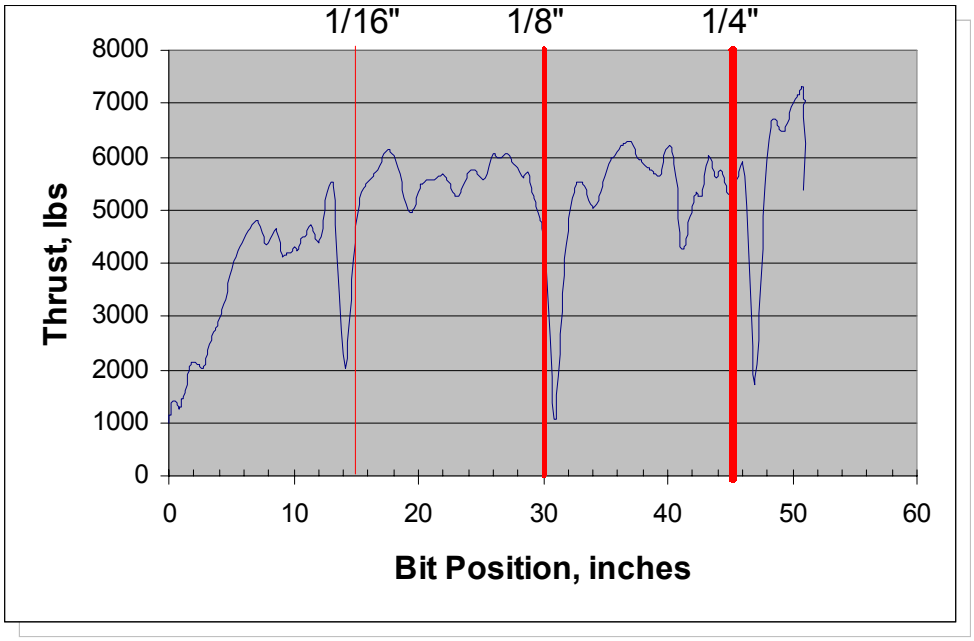

Fig. 2 Locations of the Fractures vs. Valleys in the Thrust Development Curves

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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	As detailed in item No. 1
C. Drill Parameter Data Analysis and Correlation with Roof Stability Conditions	As detailed in item No. 1
D. Software Development for Mapping of Roof Geological Conditions	As detailed in item No. 3
E. Computer Modeling to Investigate the Mechanisms of Roof Bolting	As detailed in item No. 2
F. Development of Roof Bolting Design Requirements for Implementation in the Primary Roof Bolting Cycle	As detailed in item No. 2

CONCLUSIONS

More laboratory tests have been performed in this quarter. The analysis performed on the testing data showed: (1) abnormal rotational accelerations can be used as the indicator of the rock interfaces, and (2) the sharp drops of drilling thrust and torque agree well with the locations of fractures.

REFERENCE

Luo, Y., S.S. Peng and G. Wilson, 2002, "Identification of Lithologic Changes Using DrillingParameters," Paper presented at 2002 AIME-SME annual meeting at Phoenix, AZ, Pre-print No. 02-194.