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

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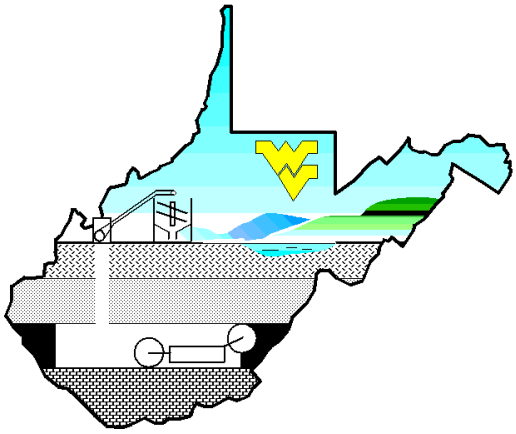

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DISCLAIMER

ABSTRACT

Field tests have been performed in two underground coal mines in this quarter. It also found from the tests that the non-drilling thrust and torque should be deducted from the acquired drilling data. . The non-drilling torque is actually higher than that is used to overcome the shear strength is proportional to the rotation rate.

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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 this quarter, field tests using the dedicated roof bolter have been performed at two coal mines operated by Consol (Fig. 1) and Peabody, respectively. In the Consol mine, the drilled roof strata were mainly consisted of soft shale. At the testing site at the Peabody mine, the immediate roof strata were soft shale layers in the lower part while hard sandstone layers were reachable by the drill rod on the top.

Fig. 1 Field Testing Site at Consol Mine in Kentucky

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.

From these field tests, it has been found that the thrust and torque required to maintain the drill system to advance and rotate without actual drilling into rock (non-drilling operation) should be deducted from the acquired data of the thrust and torque. It is also found that the torque during non-drilling operation is actually higher than that is used to overcome the shear strength is proportional to the rotation rate.

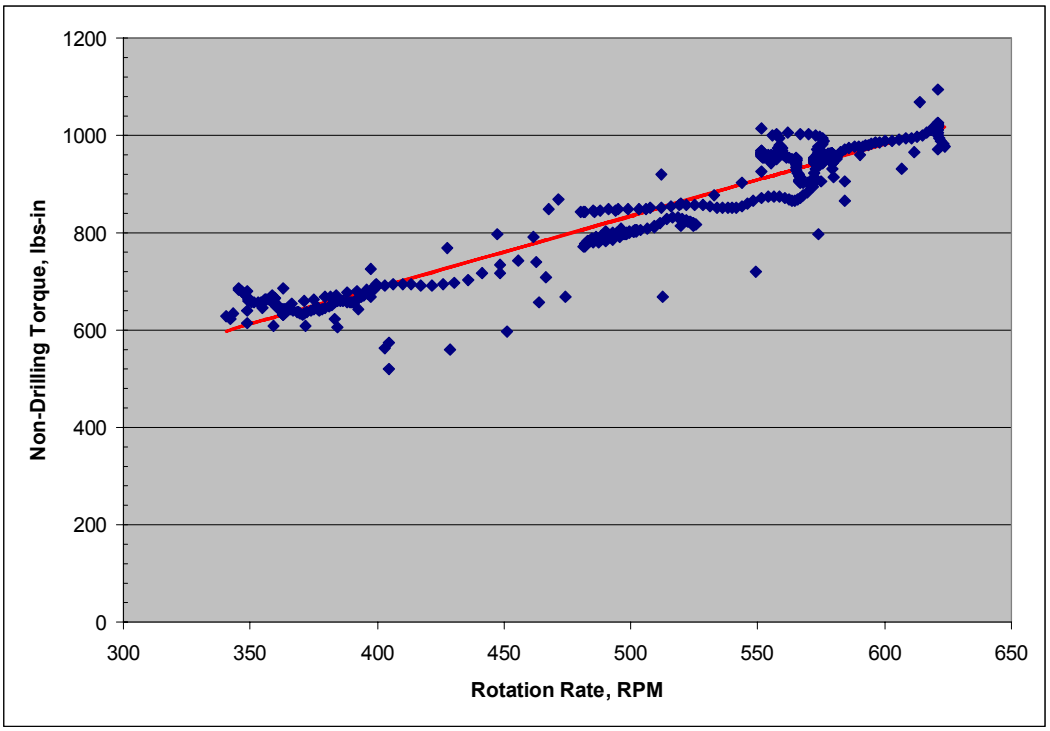

Fig. 2 Relationship Between Non-Drilling Torque and Rotation Rate from the Compensation Runs in Peabody Mine, Southern West Virginia

Development of the systematic and mechanics-based approach for interpreting the drilling parameters is continuing. This approach is able to take geometry of the drill bit and the rock failure mechanisms in rotary drilling into consideration. Therefore, the bit wear process, an important factor in drilling operation, can be considered. This approach has been proven, by the laboratory and field tests, to be more consistent and versatile than those methods based on the concept of specific energy. A technical paper reporting the development of this method will be presented at the 21st International Conference on Ground Control in Mining to be held at Morgantown, Aug. 7- 9, 2002.

2. Exploring the Roof Bolting Mechanisms

In exploring the mechanisms involved in roof bolting, finite element (FE) modeling techniques have been applied to study the supporting mechanisms using the tensioned

bolts and the full grouted risen bolts. 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. 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. 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.

Two technical papers reporting the findings of bolting modeling efforts will be presented at the 21st International Conference on Ground Control in Mining to be held at Morgantown, Aug. 7- 9, 2002.

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 is continuing in this quarter.

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

Field tests have been performed in two underground coal mines in this quarter. It also found from the tests that the non-drilling thrust and torque should be deducted from the acquired drilling data. . The non-drilling torque is actually higher than that is used to overcome the shear strength is proportional to the rotation rate.

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