Rock Mechanics Contributions and Challenges, Hustrulid & Johnson (eds)
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Roof drill – New source of low-cost roof strata information

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ABSTRACT--An ongoing research program at the Spokane Research Center of the U.S. Bureau of Mines is directed toward investigating drilling parameters (thrust, torque, penetration rate, and drill revolutions) during the drilling of roof bolt holes. A system that measures these drilling parameters, calculates the specific energy of drilling, and determines drill bit position has been developed by the Bureau and mounted on a roof drill. Through the use of a microcomputer, critical drilling parameters can be immediately interpreted and analyzed. This makes it possible to inform the operator of hazardous roof conditions. Initial results of this program are presented here.

1 INTRODUCTION

The Bureau of Mines and a western coal operator are jointly pursuing research to identify unstable roof conditions in coal mines for better roof control. The objective of this research is to detect poor roof conditions and reduce miner exposure to hazards associated with roof falls in underground coal mines. The Bureau developed a system to measure drilling parameters on a machine owned by the cooperating mine. The company will assist the Bureau in conducting field trials at its mine.

Effective ground control is the key to improved safety and high productivity in underground mining. Even though 25 pct of a typical mine's production budget is used for ground control, roof falls still occur, in part because an operator is unable to detect hazardous geological conditions. Roof falls can bury equipment and interrupt production in longwall gate entries, as well as injure mining personnel. An effective ground control program must be able to detect hazardous geological conditions to allow mine management to make decisions on whether to remove personnel and equipment or install supplemental roof support.

Since the introduction of roof bolting for mine roof support in the late 1940's and early 1950's, the mining industry has sought to use drills as probes for detecting hazardous rock conditions. This approach has been implemented using the senses of the drill operator, including the feel and sound of the drill and the appearance and smell of drill cuttings. The instrumented roof drill developed by the Bureau, enhances human senses by adding modern sensory equipment and instruments to the drill. In so doing, the roof drill is able to obtain and record more accurate information about the condition of the roof, as well as provide an instantaneous visible warning signal when hazardous roof is encountered.

2 SPECIFIC ENERGY OF DRILLING

2.1 Background

The specific energy of drilling is defined as the work required to drill through a unit volume of rock. Hence, units are in energy per volume, or newtons per cubic meter (inch-pounds per cubic inch). This is equivalent to units of compressive strength: kilograms per square meter (pounds per square inch).

The specific energy of drilling is calculated using the formula:

$$e = \text{Thrust component } \frac{F}{A} + \text{rotation component } \frac{2\pi NT}{Au},$$

where e = specific energy of drilling,
F = thrust,
A = hole area,
N = rotation rate,
T = torque,
and u = penetration rate.

For several years, it has been theorized that a direct relationship exists between the energy expended in rock drilling and the competency of the rock. Further research indicated a nearly one-to-one correspondence between the specific energy of drilling as a function of torque, thrust, penetration rate, rotation rate, the area of the hole, and the compressive strength of the drilling medium.

Possibly the earliest consideration of the specific energy of drilling as a useful rock quality index was in the early work of R. Teale of the National Coal Board, Mining Research Establishment, Isleworth, Middlesex, Great Britain. In 1965, Teale published "The Concept of Specific Energy in Rock Drilling." He developed the standard equation for specific energy that is the basis for much of the research in this area over the past two decades.

More recently, the U.S. Bureau of Mines, through a contract with Foster-Miller Associates (Lusignea and Maser 1982), a private contractor, completed an investigation that involved testing roof drill instruments for detecting hazardous roof conditions. The report concluded that it is both possible and desirable to use drilling parameters to measure the specific energy of drilling and that development of a system that measures such parameters could identify rock of inadequate strength. The recommendation was to build a real-time measurement-and-display system that would provide both a permanent log for each hole drilled and a real-time display of specific energy and bit position for the operator.

Using the Foster-Miller recommendations, the present program was developed to enhance and supplement operators' senses by applying modern sensory and instrumentation techniques to measure roof drilling parameters, such as torque, thrust, penetration rate, and rotation rate, and relating these parameters to roof conditions. The program is based on prior studies of roof control practices, geologic conditions as related to hazards, and instrumentation for drilling machinery. The objective

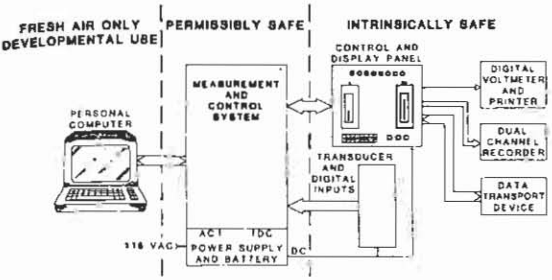

Figure 1. Diagram showing roof drill instrumentation system.

is to record and interpret roof conditions as they are encountered during drilling and to apply these data to roof support system planning.

2.2 Current design

A system, shown in figure 1, was developed by the Bureau to measure drilling parameters and calculate the specific energy of drilling as well as the drill bit position. When mounted on a roof drill, this system provides the operator with real-time displays of specific energy of drilling and drill bit position.

Through the use of a system microcomputer, interpretation and instantaneous analysis of critical drilling parameters is accomplished. This makes it possible to inform the operator of hazardous roof conditions such as voids, inclusions, or changes in strata.

In addition to real-time displays, specific energy versus bit and void position data can be downloaded to a removable semiconductor memory device. Data stored in this device (called a data transfer device or DTD) can be transferred to the surface and directly accessed with a personal computer (PC).

The drill instrumentation system consists of three separate components. The first is a PC package used only during program development and data retrieval. The PC is used outside the mine environment and never is subjected to adverse conditions underground.

The second system component (fig. 2) consists of a permissibly safe enclosure housing the measurement and control computer and other signal conditioning circuits. All lines running into and out of this enclosure are protected by barriers to prevent the transfer of unsafe currents to the transducers or the control panel. These lines are protected by flexible hose conduit.

The third system component is the control and display panel in combination with all the external transducer circuits and the DTD.

3 LABORATORY TESTS

3.1 Equipment

The equipment to be used in determining the specific energy of drilling and drill bit position has been designed and assembled and is being tested at the Bureau's Spokane Research Center laboratory. The system shown in figure 1 includes a PC, measurement and control section, control and display panel, DTD, and various transducers.

A used roof drill was acquired, repaired, and brought to SRC. This drill is the experimental platform for the research on specific energy and for future work involving expert systems. The measurement and control section is mounted on the left rear side of the bolter as shown in figure 2, in an area previously occupied by the dust collection system,

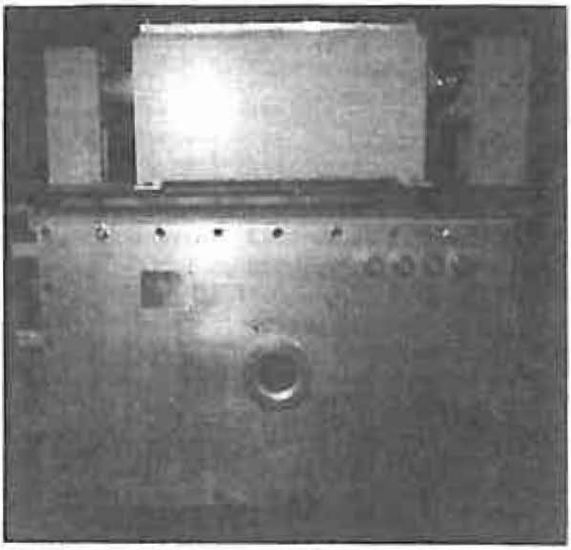

Figure 2. Power supply and measurement and control box for the Intel 8088 microprocessor.

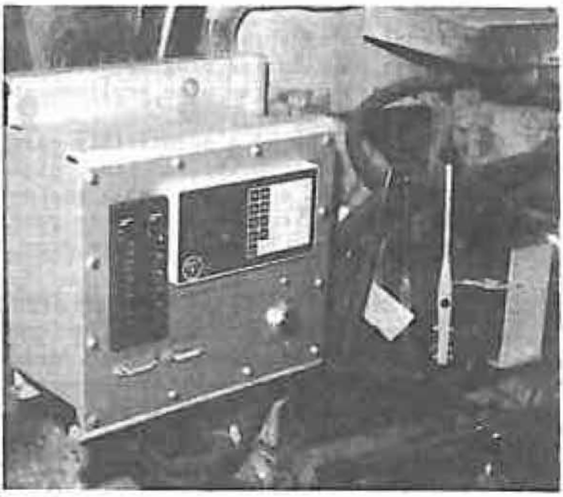

Figure 3. Drill operator control station with operator control panel and hydraulic lever for thrust control.

which is no longer needed because water washing of drilling dust is now considered to be the preferred method of dust control.

The control and display panel is mounted on the front of the roof drill next to the control levers (fig. 3), which are in constant use during the drilling and bolting sequence. This location was chosen to provide maximum visibility and access for the operator. The DTD is connected to the control and display through a short cable. These components, along with the signal transducers, make up the major hardware components of the system.

3.2 Preparation

To prepare for the laboratory tests, concrete test blocks were constructed. These blocks were made up of alternate hard and soft layers, and each layer was deliberately cast with voids at specific levels (fig. 4). Cores were taken from these blocks at the time they were poured to provide a means to check system calibration. These blocks are to be used to determine the accuracy of the calculations for specific energy and drill bit position.

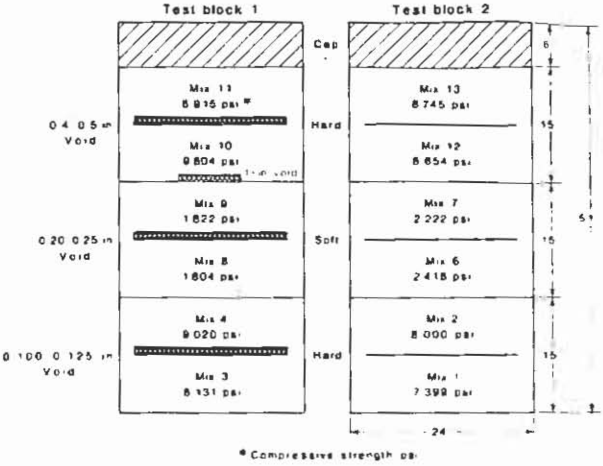

Figure 4. Test block data diagram.

3.3 System testing and calibration

The objective of laboratory tests of the drill was to evaluate how well the machine's instrument system could measure operating variables. To provide a reliable and repeatable means of sensor and system calibration and to test torque and rpm, a hydraulic brake was built. With the addition of a thrust plate member, thrust components could also be calibrated. Because torque, thrust, and rpm are essential to calculating the specific energy of drilling, it is necessary to determine these parameters accurately. The Lebow torque, thrust, and rpm transducer provide calibration reference signals for evaluation of the drill circuits. Simultaneous recording of both the Lebow and drill sensors allows direct correlation and calibration.

A strip recorder and two data acquisition systems (DAS) provide a hard copy and a digital record of calibration data and drill system sensed data. The torque, thrust and rpm data from the two sources are recorded on the strip recorder and are fed into the corresponding DAS. Thus the system provides an immediate readout and a digital recording to interface with a PC. The variables sensed by the drill can also be displayed on the operator control panel.

3.4 Drilling simualtion

The next step is to simulate drilling in roof-like material in the laboratory. A steel frame supports specially designed and manufactured blocks containing layers of concrete of various compressive strengths. Voids are deliberately created in the blocks to test the void detection system of the drill. An analysis of the test results is currently underway.

Field testing will be completed during 1990 and will consist of drilling up to 500 holes and recovering 12 cores from the cooperating mine. This should provide the data necessary to establish the importance of using the specific energy of drilling as a real-time indicator of mine roof conditions.

4 FUTURE PLANS

Plans include an extension of the capability of the existing system to incorporate automatic control. Using the existing transducers and onboard computer, an algorithm will be written to control drilling efficiency. Two hydraulic servocontrol valves will be added to control thrust and rpm to attain a maximum penetration rate. As a result, equipment maintenance and downtime will be reduced and the useful life of other drilling components will be extended.

Plans also include the development of software that could be used both to achieve better drill control and to provide additional data on rock structure. With proper sensor location, an expert system could determine imminent failure of roof strata.

Another area where future research will make contributions is the enhancement of drill hole data processing. By integrating drill hole data into an intelligent mine-wide monitoring system, a geostatistical database could be developed that would provide valuable input to ground control decisions such as how to modify roof control plans or whether to add supplemental ground support.

It is anticipated that continued progress in these areas of research by the Bureau will significantly improve reliability, economy, and safety of roof support and other related coal mine operations.

5 CONCLUSIONS

By monitoring drilling parameters to obtain the specific energy of drilling, rock of inadequate strength can be identified. This information can then be used to determine appropriate supports for the given situation.

Research has led to the improvement of instruments for measuring the drilling parameters of torque, thrust, penetration rate, and rotation rate, and improved the display and recording of data for operator and mine engineer use.

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COLORADO SCHOOL OF MINES / GOLDEN / 18-20 JUNE 1990

Rock Mechanics Contributions and Challenges: Proceedings of the 31st U.S. Symposium

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A.A. BALKEMA / ROTTERDAM / BROOKFIELD / 1990

Sponsored by:

US National Committee for Rocks Mechanics and the International Society for Rock Mechanics

Assisted by:

Colorado School of Mines
US Bureau of Mines, Denver Research Center

The texts of the various papers in this volume were set individually by typists under the supervision of each of the authors concerned.

Published by
A.A. Balkema, P.O. Box 1675, 3000 BR Rotterdam, Netherlands
A.A. Balkema Publishers, Old Post Road, Brookfield, VT 05036, USA

ISBN 90 6191 123 0

Printed in the Netherlands