CHARACTERISATION OF ROCK IN UNDERGROUND MINES FOR APPLYING DRILLING AND BOLTER DRILLING USING ARTIFICIAL INTELLIGENCE

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ABSTRACT

BACKGROUND
Mining process is very important in the modern society because of its advantage. Despite of many recent advances in mine health and safety, roof collapse and instabilities are still the leading causes of injury and fatality in underground mining operations. As we know that the mining is the very important process, improving safety and optimum design of ground support requires good and reliable ground characterisation. In the mining process, the characterisation of rock is also very important because before mining we need to have a good place and soil strength. Interpretation of the data obtained from roof bolt drilling can offer a good and reliable source of information that can be used for ground characterisation and ground support design and evaluation. The actual measurements on the samples of the roof and wall strata from the exploration bore are reliable, but the related holes are far apart, thus unsuitable for design purposes.

KEYWORDS
Artificial Intelligence, Rock Classification, Bolter, Underground Mine, Drilling.


BACKGROUND

In the mining area, most of the accidents are caused due to because of roof falling and explosion within the tunnel.[1] A review of the statistics of fatalities and injuries in various industrial settings in US between 1988 and 1997 (NIOSH, 2000) showed that the “Fall of Ground” is the second leading cause of 6% of the total fatalities reported in underground mining. Brief screening of similar data in 2006 and 2010 (CDC, 2013) indicated the same trend and proportions.[2] A quick review of published literature from other countries also showed that the same trend is true elsewhere in the world (Mark, 2014), despite some improvements in the overall statistics and a reduction in total number of injuries in underground mining and tunnelling operations. This reveals that roof falls and resulting injuries are fairly persistent, if the conditions relative to health and safety performance of underground mines are not to be improved. The situations are perhaps more serious in smaller mines with less automation and mechanisation.[3]

Roof characterisation is essential for design of safety and cost of effective ground supports in underground space. The typical geological features used for roof mapping include rock type, rock strength, voids, cracks, discontinuities, shear zones, beddings and similar geotechnical features. Ground characterisation in underground environment can be performed by various methods such as visual observation and geophysical loggings, bore scoping, rock mass rating of the roof and walls and instrumented roof bolters or jumbo drills.

On the other hand, rock mass rating cannot usually be determined in advance of mining, since it requires some onsite geological measurements and observations.

Ground Characterisation by Instrumented Drills

Before going to characterise the rock mass, the idea of using drilling parameters is also essential in the mining.[3] To characterise the rock either at the working face while drilling the blast round at the heading or when drilling into the roof and walls for support installation has been around for a long time.[4] It is just that the accuracy and reliability of various sensors have been improved drastically in recent years and the required computational power of the computers has reached to the point that on board data processing for ground characterisation could be a reality at present.

The early work on this subject includes Frizzell et al (1992) who presented the initial results of a research program by applying the AI technique at the Spokane Research Center of the US Bureau of Mines directed toward investigating drilling parameters (thrust, torque, penetration rate and drill revolutions) during the drilling of roof bolt holes.[4,5] Signer and King (1992) and King et al (1993) explained the unsupervised learning technique and the expert system, which had an interface with the instrumented roof bolter to determine geological features, select the significant roof features in relation to the support parameters and suggest improvements to the support design.[6]

The Utt (1999) and Utt et al (2002) applied neural network technology to the classification of mine roof strata in terms of relative strength. They presented the results of the above-mentioned project as a whole report and stated that it was expected that a remote control system could allow a drill operator to be positioned in a safer location and be less likely to be under a roof fail.[7,8] LaBelle et al (2000) and LaBelle (2001) instrumented a portable hydraulic powered coal mine roof bolter drill to classify rock strata in coal mines. They used a neural network to classify material lithology where the inputs to the neural network were sensed drill parameters such as thrust, torque, rotary speed and penetration rate as...
well as information derived from these sensors over time (Figure 1). A research team of West Virginia University performed a study on the characterisation of mine roof using the drilling parameters of an instrumented roof bolter drill, which started in 1999.\cite{1} A series of manufactured roof rock blocks was tested in the laboratory. Some underground tests were also conducted.

1. The feed pressure tends to drop to the level of drilling in the air when a void/fracture in rock is encountered. This parameter can be used to detect the voids/fractures. The laboratory and field tests showed that a very high prediction percentage has been achieved for the 3.2 mm (1/8 inch) or larger voids.
2. The strength of roof rock can be determined/classified based on the magnitude of feed pressure.
3. A new software package called Mine Roof Geology Information System (MRGIS) was developed to allow mine engineers to make use of the large number of roof drilling parameters for roof support design.

A real time Drilling Display System (DDS) for the J.H. Fletcher and Co. HDDR dual head roof bolter for rotary roof bolting was developed and tested in the field (Collins et al, 2004). The study showed that a fairly accurate representation of void or separation locations in the mine roof can be determined from sensor data recorded during production bolting cycle. This information can be presented to the machine operator in a usable concise real time format. In a recent project of the West Virginia University, the software was modified to communicate in real time with the DCU and display the information as the holes were being drilled (Anderson and Prosser, 2007).

Ongoing Research of Instrumented Roof Bolt Drilling Void Detection

In the modern process of analysis, the research team at the Pennsylvania State University has been working on improving the accuracy of DDS void detection system of the J. H. Fletcher and Co. using the AI technique as well as enhancing the machines ability to identify the rock strength as an attempt to complement the MRGIS and develop a 3D visualisation of the ground conditions in the mine roof.\cite{2} Testing of roof bolter drills has been underway for two years.\cite{2}

One of the initial steps in improving the system was to add additional sensors to complement the existing instruments and also take a closer look at the data collection rate as well as the feature detection algorithm.\cite{3,4}

This has been accomplished by using a higher data rate and also a new detection routine using cumulative sum (CUSUM) algorithm. The details of the CUSUM method can be found in Basseville and Nikiforov (1993).\cite{5}

Rock Strength Evaluations

Figure 2 shows that various parameters can be monitored and combined to identify the rock and assign strength to each rock being drilled. This is done through an analysis of probability of being in a certain rock based on the registered distinctions, which allows the rock to be placed in a certain class.\cite{6}

Field Testing and 3D Visualisation

Testing the system in the field is the best proof of functionality of the system and its ability to detect the voids and to identify the rock types based on their respective strength.\cite{7} This is the subject of parallel testing and development of relevant borehole probes that allow for identification of various rock types and locations of fractures and joints so that the data obtained from the drill can be used for training the system to characterise the ground as the drilling proceeds in the field.\cite{8} The ultimate goal of this study is to develop a 3D view of ground conditions as well as contour line of roof/wall hazards by combining the information obtained from various sources including the routine bolting of the underground working as part of ground support installation. For the time that no equipment or device is available, which can evaluate rock strength within a small diameter, short borehole is drilled upward, which is typical of roof bolting boreholes. For this reason, initial testing is underway to develop a borehole scratcher probe that can scribe a small groove in the side of the hole and estimate rock strength based on the forces acting on the scribe.

CONCLUSIONS

As we know that the mining is the essential process, which is mostly required nowadays to fulfil our day-to-day requirement. But, to go for the mining process, we need to have many safety prerequisite and analysis of the mines are

\[\text{Figure 1. Concrete Drill Hole Sensor Recordings for One Drill Hole}\]

\[\text{Figure 2. Distribution of Drilling Data Points and Boundary Planes for Estimating Rock Data. One PSI is Approximately 6.895 kPa.}\]
also important. We also know that in the mines, area most of the accidents occur due to roof falling and explosion, so many improvements have been made on the roof characterisation by instrumented roof bolter using the AI technique. However, there are still several issues that must be solved to improve the accuracy and precision of the void detection system to locate joints with smaller aperture. The improvement in characterising the rock and rock mass features will allow for improving the understanding of the ground conditions and rock mass classifications in addition to the effectiveness of systems used for ground support. This is a great application of AI and Neural network, which provides us the platform to analyse the rock before we go for mining.

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