

Evaluation of Rock Burst in Deep Coal Mining By Using the Forensic Engineering

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ABSTRACT

Rock bursts remain an important problem in longwall coal mining. These bursts are due to a sudden and severe failure of rocks from a high stress concentration in deep underground excavations that occur with the instantaneous release of strain energy stored in the rocks. They can potentially cause irrecoverable damage to equipment and personnel, thus accurate rock burst prediction and control is expected to be carried out by the mine design engineer. As a result, this can constitute major challenges for said engineer.

In this paper, forensic engineering has been used to evaluate the possibility and extent of rock bursts in deep coal mining. For this purpose, established mining engineering principles, including factors influencing the severity of rock bursts, have been incorporated in the forensic engineering technique. The analyses took place in five steps:

- Assessment of regional and local conditions prior to the event
- Assessment of conditions after the event
- Hypothesize plausible ways in which pre-event conditions can become post-event ones
- Search for evidence that either denies or supports various hypotheses
- Apply engineering knowledge to relate the various facts and evidence into a cohesive scenario of how the event may have occurred.

The paper concludes by demonstrating a method for predicting rock bursts and preventing their reoccurrence. The methodology used in this paper, together with the results obtained, can serve as useful tools for the coal mine design engineer in the primary evaluation of rock burst potential in underground coal mines.

INTRODUCTION

A rock burst is defined as the sudden and great failure of rocks due to a high stress concentration in deep underground mines. This phenomenon occurs with the instantaneous release of strain energy that is stored in the rocks, and can cause irrecoverable damages to both equipment and personnel (see Figure 1). Rock bursts pose a

hazard owing to their lack of predictability; in fact, research into understanding rock burst mechanics and implementing techniques for their monitoring and prediction has been taking place for over 50 years.



Figure 1. Rock burst damage and fragmentation.

Generally, mine rock bursts may be divided into stress, stroke and stroke-stress events. Mine and tectonic rock bursts have also been identified [1].

Rock bursts occur as a result of carrying out mining activity either during mining or when mining has been finished. Tectonic rock bursts occur within tectonic zones. Stress rock bursts are the result of slow, quasi-static increase of stresses inside the bed, in the vicinity of workings, which causes a sudden release of gathered energy. Stroke rock bursts are the result of sudden application of force following the break of thick monolithic rock layer in the bottom or top of deposit, and its relocation. Tectonic rock bursts are, to some extent, similar to stroke bursts.

Such interpretation of stress and stroke rock bursts refers to extreme cases. However, there is a wide range of stroke-stress events between them; when at high values of stress, condition constituents, even relatively slight impulse of stroke, coming from the rock-mass surrounding the layer, can result in a rock burst.

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The issue of rock burst hazard control refers to nearly the entire production process, from planning of mining works to drift excavation and deposit mining.

FORENSIC ENGINEERING

A number of definitions of forensic engineering are available in the literature. For example, Specter (1987) defines forensic engineering as “the art and science of professional practice of those qualified to serve as engineering experts in matters before courts of law or in arbitration proceedings.” Similarly, Noon (2001) defines forensic engineering as “the application of engineering principle, knowledge, skills and methodologies to answer questions of fact that may have legal ramifications.” Forensic engineering now has its own specialist societies, consulting firms, conferences, literatures and university courses and has attracted popular attention through television programs and books.

Following Noon (2001), in the context of underground construction, forensic engineering will be taken in this research to be the application of engineering principles and methodologies in order to determine the cause of a performance deficiency, such as a collapse, in an excavation or a rock burst and the reporting of the findings, usually in the form of an expert opinion within the legal system.

Ground control forensics is concerned typically with investigations of failures of constructed facilities, rock falls, rock bursts and other accidents in mines.

Initially, only the end result is known. This might be a collapsed bridge, a sunken highway, damaged equipment or wrecked vehicles. A forensic engineer gathers evidence to reverse-engineer the scenario and determine how the failure or event most likely occurred. Moreover, forensic engineering investigations involve a number of steps. In general, the engineer collects several types of evidence, evidence then analyzes various types in order to determine the who, what, where, when, why and how of the deficient performance or failure of engineered facilities, systems and products, including accidents. When a failure is successfully explained, it means that it has been reconstructed.

Forensic engineering is similar to Failure Analysis (FA) and Root Cause Analysis (RCA) with respect to the science and the engineering methodologies employed. Often the terms can be used interchangeably. However, there are implied differences in the emphasis between the two descriptions that are worth exploring.

FA usually suggests the determination of how a specific component or part has failed. Typically, FA is concerned with material selection, design, product usage, methods of production and the mechanics of failure within the part itself.

On the other hand, RCA places more emphasis on the managerial aspects of failures. The term is more often associated with the analysis of system failure than the failure of a specific part, and also how procedures and managerial techniques can be improved to prevent the problem from reoccurring. RCA is often used in association with large systems with complex but interactive parts. A simple analogy is a spider web, a complex system of woven strands that form a structure that is both flexible and strong.

If specific strands begin to fail or tear, the entire web becomes ineffective. However, if carefully selected unimportant strands are broken, the web can remain intact and serve the designed purpose [2].

PRIMARY STEPS FOR EVALUATION OF ROCK BURST USING FORENSIC ENGINEERING

For the evaluation of rock bursts in deep coal mining, the analyses were carried out in five steps. The steps can take anywhere from a couple minutes to over a day to complete, depending on the complexity of the failure.

Assessment of regional and local conditions prior to the event

It is best to take an assessment of the mine design fundamentals at this point. A simple assessment of a roof rock's strength, be it weak, moderate or strong, is usually all that is required at this point. In this step, some of the geological factors that have an impact on the rock burst should also be considered and correctly evaluated. These factors include tectonic and presence of discontinuity planes, geomechanical characteristics of rock mass, rocks' tendency to generate mine tremors, depth of mining and its related rock-mass pressure.

One of the most important factors that should be considered is a high primary pressure of rock mass, resulting from both a sizable mining depth and residual pressure resulting from tectonic disturbances of the deposit. In addition, paying particular attention to the immediate roof and bolted horizon is also important at this step. Are there any geological structures in the area or signs of mining induced or horizontal stresses? What is the depth of the excavation and the condition of the pillar? These are examples of questions that a forensic engineer is faced with at this point.

Assessment of conditions after the event

This stage of the assessment is ideal to examine the bolting or support system used in the immediate and adjacent areas of the rock burst. The roof control method is one of the most important factors that should be evaluated at this step. Examination of the support system is associated more closely with “failure analysis,” meaning that, if bolts, plates or other support system components appear to have contributed to the rock burst event, then a safe attempt should be made to obtain samples or specimens. How many bolts were installed to support the area, and were they installed according to the approved roof control plan? This can be only estimated by examining the bolting patterns and support installations that are in the immediate section and entry. The most critical factor that should be considered is the local concentration of stresses caused by mining activity. It may be generated by an improperly selected mining method and a wrong mining pattern or strong roof rocks over the mined-out area.

Hypothesize plausible ways in which pre-event conditions can become post-event ones

This step is often the most critical step in determining the cause and contributing factors to a rock burst. All of the mine design factors including geology – complete with weakness features and structure – and roof control method, mining method, concentration

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of mining operations and spatial limits of mining operations have been obtained. Ground control experiences and previous observations really begin to pay dividends at this step.

During this phase, at least three possible explanation or hypotheses should be considered. The goals during this step are to create realistic scenarios using the information that is available or can be determined in order to explain why the event occurred. Creating these scenarios can also be an interactive exercise with operations, safety and the engineering staff. Working your way around the major factors can assist in quickly developing a list of plausible causes for the rock burst.

Search for evidence that either denies or supports various hypotheses

The main purpose of this step is to determine which of the established hypotheses fits the observed conditions of the rock burst supported by ground control calculations and evidence. There may not be a single cause that can be determined for the question of why in the rock burst event. To the contrary, two or three factors that are closely related to each other and have a history of causing safety problems can potentially sometimes explain the failure. Every important variable is, as a result, examined and engineering calculations are carried out in order to determine the validity of the observation.

Apply engineering knowledge to relate the various facts and evidence into a cohesive scenario of how the event may have occurred

In this step, scenarios are re-created starting with the excavation, geology and mine design. This step does not require the engineer to consider the rejected scenarios and hypotheses and only needs to take into account the applicable and approved ones. This

includes details of the original mining method, roof control method and geomechanical rock mass characteristics. A list has to be comprised, including important components and factors indicating effects on the failure's root cause. Lastly, recommendations have to be made in order to minimize any future occurrences.

CONCLUSIONS

This paper's main aim was to propose and illustrate that forensic engineering can be a useful technique in studying and evaluating rock bursts. Rock bursts are complex and, most of the time, unpredictable. This five-step system can be a good methodology to explain complex rock bursts. Also, by using this technique and methodology, most rock bursts can be explained and minimized in future development. However, this technique needs to be used in more case studies for evaluation of rock bursts in order to correctly determine its validity.

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