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Efficient mine microseismic monitoring

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Abstract

During the past 20 years, the microseismic technique has grown from a pure research means for rockburst study to a basic industrial tool for daily safety monitoring at rockburst-prone mines. This article examines the important issues for efficient mine microseismic monitoring programs. The key technical issues for such a program are discussed from three aspects: monitoring planning, data processing, and microseismic event location. An efficient monitoring program would be impossible without a firm commitment of the mine management. Issues related to the management and mine operations are discussed, including monitoring program integration, efficient use of microseismic data, and the benefit of monitoring programs for mine safety and productivity.

Keywords: Microseismic; Rockburst; Source location; Ground control; Mining

1. Introduction

Rockbursts and coal bumps are sudden and violent releases of energy stored in rock masses and geological structures. They have been a persistent threat to mine safety, causing catastrophic failures of mine openings, paralyzing mining operations, damaging mining equipment, and posing a severe safety threat to underground workers. In 1958, a rockburst at the Springhill Coal mine in Nova Scotia claimed 75 lives. In the U.S., a total of 100 rockburst-caused fatalities were reported in the last 60 years (Blake and Hedley, 2003).

The energy released by a rockburst can be staggering. In 1995, a rockburst with a local magnitude of 5.2 M_L was recorded at the Solvay trona mine, Wyoming, when an entire 1000 m × 2000 m panel collapsed. The US coal mining industry has experienced bumps since the 1920s, with magnitudes up to 4.5 (Blake and Hedley, 2003).

The technique that is widely used for studying rockburst activities is the microseismic monitoring technique. The technique utilizes signals generated by the material to study fracture/failure processes. The real time monitoring capability of the microseismic technique, in terms of event source location, magnitude and source mechanisms, makes it an ideal tool

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for studying mine seismicity and related ground control problems.

The phenomenon of the emission of micro-level sounds by stressed rocks was first discovered in the late 1930s by two U.S. Bureau of Mines (USBM) researchers, Obert and Duvall, when they carried out sonic studies in a deep hard rock mine (Obert, 1975). In the early 1960s, South African researchers began to utilize this phenomenon to study the rockburst problem associated with deep gold mines (Cook, 1963). This early study convincingly demonstrated the feasibility of the rockburst location by the microseismic technique, the central element of mine microseismic monitoring.

In the middle of the 1960s, the USBM started a major research program in order to make the microseismic technique an efficient tool for mine safety monitoring. The hardware and software developed from this program, as well as the research and field tests carried out during this period, laid the foundation for the industrial use of the microseismic technique (Leighton and Blake, 1970; Leighton and Duvall, 1972).

From the middle of the 1980s to the early 1990s, severe rockburst problems occurred spontaneously in Canadian mines. Over 20 rockburst-prone mines installed microseismic systems for daily monitoring purpose. From the late 1980s to the 1990s, large-scale rockburst research was carried out in Canada, sponsored by the Canadian federal government, the Ontario provincial government, and major mining companies. This research fundamentally changed the role of the microseismic technique in the Canadian mining industry. It is no longer a pure research tool, but the basic monitoring means for mine safety and ground control.

This article examines the important issues for efficient mine microseismic monitoring programs. The discussion is carried out from three aspects: monitoring planning, data processing, and microseismic event location. Although the focus of this paper is the technical issues, it is important to note that an efficient monitoring program would be impossible without a firm commitment from the mine management. For this reason, we will also discuss issues related to the management and mine operations, including monitoring program integration, efficient use of microseismic data, and the benefit of an efficient monitoring program for mine safety and productivity.

2. Planning and optimization of monitoring systems

Careful planning is the foundation for establishing an efficient monitoring program and has a profound impact on the system's long-term performance. There are three important issues to be resolved at this stage: engineering assessment of monitoring objective and monitoring condition; determination of the monitoring system size (number of channels); and optimization of the sensor array layout. Also, the harsh mining environment requires a rigorous maintenance program because monitoring systems degrade rapidly.

2.1. Engineering assessment of monitoring objective and monitoring condition

The first task at the planning stage is a thorough assessment of monitoring objectives, including target areas, monitoring accuracy, and associated monitoring conditions. Since mining is a dynamic process, this assessment should take into account both short-term and long-term monitoring needs.

In order to achieve this goal, a comprehensive analysis should be carried out on potential rockburst hazards in relation with the mining conditions, such as mining method, mine layout, ground control practice, mine development operations, geological materials and structures, and stress conditions at the mine site. As a result of this engineering assessment, the size of the monitoring system can be determined. This analysis should also yield useful information on feasible locations for sensor installation.

2.2. Using a large channel system

The number of channels needed depends on several factors. The most important ones are the size of the area to be covered, the location accuracy required, the signal level expected, and rock formations. An initial estimation may be made with the reference of the mines with the similar conditions.

It is always good practice to use a relatively large channel system. Why is a large channel system critical for daily monitoring programs? A simple answer to