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Application of underground microseismic monitoring for ground failure and secure longwall coal mining operation: A case study in an Indian mine

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ABSTRACT

Longwall mining technique has been widely used around the globe due to its safe mining process. However, mining operations are suspended when various problems arise like collapse of roof falls, cracks and fractures propagation in the roof and complexity in roof strata behaviors. To overcome these colossal problems, an underground real time microseismic monitoring technique has been implemented in the working panel-P2 in the Rajendra longwall underground coal mine at South Eastern Coalfields Limited (SECL), India. The target coal seams appears at the panel P-2 within a depth of 70 m to 76 m. In this process, 10 to 15 uniaxial geophones were placed inside a borehole at depth range of 40 m to 60 m located over the working panel-P2 with high rock quality designation value for better seismic signal. Various microseismic events were recorded with magnitude ranging from −5 to 2 in the Richter scale. The time-series processing was carried out to get various seismic parameters like activity rate, potential energy, viscosity rate, seismic moment, energy index, apparent volume and potential energy with respect to time. The used of these parameters helped tracing the events, understanding crack and fractures propagation and locating both high and low stress distribution zones prior to roof fall occurrence. In most of the cases, the events were divided into three stage processes: initial or preliminary, middle or building, and final or falling. The results of this study reveal that underground microseismic monitoring provides sufficient prior information of underground weighting events. The information gathered during the study was conveyed to the mining personnel in advance prior to roof fall event. This permits to take appropriate action for safer mining operations and risk reduction during longwall operation.

1. Introduction

The two underground mining methods for coal extraction are room-and-pillar and longwall. Longwall mining is a technique where a long wall of coal is mined in a single slice on a series of self-advancing hydraulic roof support. A longwall machine is an integrated system consisting a roof support, coal cutting and transportation. The roof is supported by a hydraulically driven shield which moves forward as extraction progresses along the panel. Most of the roof supports are made of canopies with two to four hydraulic legs fitted in the base to prevent falling rock fragments and they are kept along the longwall face. The conveyers belt is placed in the ground surface such a way that extracted cutting coal can fall on the conveyor belt for further transportation to the desired location.

As the longwall miner advances along the coal panel, the roof behind the miner's path is allowed to collapse. Nowadays longwall mining technique is used worldwide for its safe mining process. However, during the extraction of coal in the panel, the roof strata start collapsing and fracturing inside the longwall mines. This rock mass behavior challenges mining engineers understanding of the real scenario with respect to the advancement of the coal cutting panel. Many cases have been noticed where miners are trapped due to sudden roof collapse and stayed several hours prior to safety rescue operations. Longwall mining operation in coal mines commonly causes breaking of roof in the caving areas. The surrounding stratum of the caving areas causes vertical subsidence. Apart from the vertical subsidence, there are also lateral movements that take place towards the cave areas which in turn causes bending, stretching and compression. Such problems are known in the mining industry and are a major safety concern for the safe handling. Hence, the understanding of the longwall strata behavior is paramount for mine design and enhanced productivity.

To understand the caving behavior of longwall face, mining engineers use instruments like stress cell, extensometer and convergence meter. These are used normally at the face position and not covered surrounding cave areas. Due to this reason, it encourages improper information about the rock mass behaviors in the dynamic environment. Apart from this, it is unable to locate the origin of the fracture position

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initiated and does not explain about the dynamic behavior of roof strata. Time domain reflectometry monitoring (TDRM) provides tensile failure roof as well as rock wall. This is one of the most expensive and time taking process which provides the limited information of caving processes of longwall mine. However, underground microseismic monitoring technique can provide both the source location of the roof strata and information of fractures. Underground microseismic monitoring can also help to map rock fracturing in real time. Every fracture radiates energy within a zone of weakness inside the mining area, which can be measured in the range of −5.0 to 2 on the Richter scale also known as microseismic events. The overburden pressure of the roof strata builds up stress which leads to the generation of fractures and eventually to rock failure anywhere beneath the surface to the coal seam. Therefore, fracture origin point can be detected through microseismic monitoring technique which allows getting the event locations.

To overcome these massive problems and to get prior information of strata behavior in the Indian coal mining industry, a real time microseismic study has been carried out for the first time during 2001–2004 in the coal panel-P2 of the Rajendra longwall underground coal mine, Shohagpur, Madhyapradesh, India. The microseismic system is divided into three parts namely geophones, communication line and surface monitoring station. The minimum 10 number of uniaxial geophones were placed inside a borehole of 40 m to 60 m depth with high rock-quality designation (RQD, 60–80%), a rough measure of the degree of jointing or fracturing in a rock mass. The underground geophones were grouted firmly inside the boreholes ensuring no loss of signals with the ground to make a homogeneous surrounding. The area is located under the Rewa coalfield at latitude 23°08′12″ to 23°10′10″ and longitude 81°28′05″ to 81°30′50″E. The location map of the study area and the coal panel-P2 are shown in Fig. 1. The target coal seams are present at 68 m to 74 m below the ground surface. The roof of the coal seam is composed of shale, alluvium, and sandstone. Real time monitoring generates a seismicity map of the area covering coal panel. By studying the microseismic parameters of the operational area, it is possible to detect stress distribution zones, zone of weakness, prior to roof fall information, crack and fracture propagation, and other seismic source parameters.

A case study is discussed here by calculating and correlating various seismic parameters like activity rate, seismic stress distribution, seismic viscosity, seismic energy index, seismic volume, seismic potential energy and seismic moments. Apart from this microseismic activity in the block area, initiation of crack and fracture propagation width, identification of high and low stresses distribution zones and finally occurrences of roof fall information have been studied.

2. Overview of previous work

Underground microseismic studies for mining operations have been carried worldwide. Buchanan and Jackson (1986), acknowledge the existence of microseismic monitoring in Eastern Europe. Study of source parameters and scaling relations for mining induced seismicity which can provide higher resolution image, fracture zone and source mechanism studied by various researcher (Phillips et al., 1997; Rowe et al., 2002; Mendecki, 1997; Swanson et al., 1992; Gibowicz and Kijko, 1994; Gibowicz and Lasocki, 2000 and Oye et al., 2005). Seismic moment tensor of a mining-induced tremor discussed by McGarr, 1992; Trifu et al., 1995, Hatherly et al. (1997) and Mercerat et al., 2010. Heasley et al. (2002) studied the three-dimensional microseismic activity associated with a deep longwall coal mine to understand rock failure, redistribution of stress and goaf information. Analyses show the events activity rate and the events information. Microseismic monitoring for strata behavior was studied by Sivakumar et al. (2005). Cheng et al. (2006) studied the microseismic monitoring technology of shock bump caused by key stratum movement. Cheng et al. (2007) discussed the C-Shaped strata spatial structure and stress field in longwall face using microseismic monitoring. They studied the pressure distribution, distinguishing the dangerous areas of rock burst measurement. Luo et al. (2009) studied the roof fracture process and stability using the microseismic method. Cheng et al. (2009) deliberate the inversion of high mining pressure distribution and technology for preventing dynamic disasters using microseismic monitoring technique in the longwall face. Mendecki et al. (2010) discussed about quantification of seismic sources and seismicity for seismic hazard assessment and rock mass stability analysis. Gochioco et al. (2012) studied the safety and the productivity of the longwall coal mines using multidisciplinary tools like geology, geophysics, and geohydrology and ground control for detecting potential anomalies that create adverse impact to the

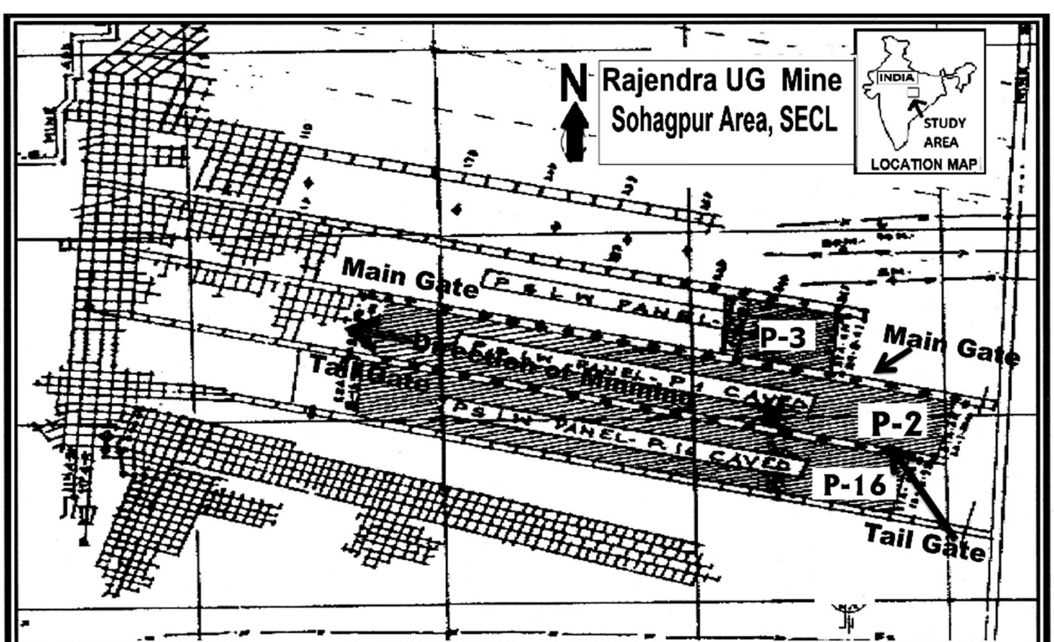

Fig. 1. Location map of the study area of Rajendra longwall underground coal mine of Panel-P2 in Sohagpur area. Map shows tail gate, main gate and direction of mining with its surrounding panels.