Source Location of Rock Burst in the Mines of Kolar Gold Fields

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Abstract: ***The rock burst problem is very common in the mining environment and it posses severe danger, especially when the mining operation reaches a greater depth like the mines of Kolar Gold Fields, South African Gold Mines and other mines all over the world. The rock bursts are continuing even after the closure of mines. These rock bursts are being recorded at present using single station recorder (Strong Motion Accellerograph) to compute the epicenters. The source location rock burst is achieved to meet the objective of the present work. On the other hand, multi channel (network) systems provide the capability to locate the source of individual event precisely and thus the problem area can be delineated for safety and stability purposes.***

Keywords: Rock burst, Seismograph, Strong Motion Accellerograph, Epicenters, seismic waves.

1. Introduction

1.1 Historical Perspective

Man made earthquakes (Rock bursts) are becoming quite common in highly stable areas on account of their indulgence in quarrying and mining. It is compelled to resort to this technique to fulfill the growing demand of the industry for the development of mankind. The problem of Rock burst in world mining science and practice is more than hundred years old. But the problem is real; the urgency of solving it grows steadily due to increasing depth of mining deposits, more extensive excavation volumes, improvement of mining engineering techniques, etc. All these factors offer ample scope for progress in the controlled, safe utilization of an enormous reserve of potential energy stored in rock mass to facilitate mining and to reduce mining costs. Mining is accompanied by a disturbance of original equilibrium which was present prior to mining and this means a change in stress distribution in the rock mass.

1.2 Rock Burst

Rock burst is a sudden failure of rock characterized by the breaking up and expulsion of rock from its surroundings, accompanied by the violent release of the energy. The consequence of sudden and violent release of stored strain energy in a rock mass near the mine opening results in rock burst. The strain energy becomes seismic or shock energy and travels through rock as a seismic wave.

According to early records [1], the first rock burst reportedly occurred in a stope below 960 ft in Oorgaum mine, Kolar Gold Fields, which later become a part of a champion reef mine in 1898. Rock bursts were classified in the early days as 'Air-blasts' and Quakes' depending on their intensity and area of damage. At shallow depths, these problems were not critical except while mining shaft pillars and in exceptional cases ore shoots which were highly stressed due to juxtaposition of faults. However, they become serious towards the 1930's as mining reached greater depths, particularly when the ore body to be mined was associated with faults, dykes and pegmatites, all involving a plane of weakness. Large rich ore shoots have been completely damaged and rendered unproductive as a result of severe rock bursts. The geometry of mining operation has an important role to play in the genesis of rock bursts [2]. A view of drive in mines before and after the major rock burst is shown in Figure 1.

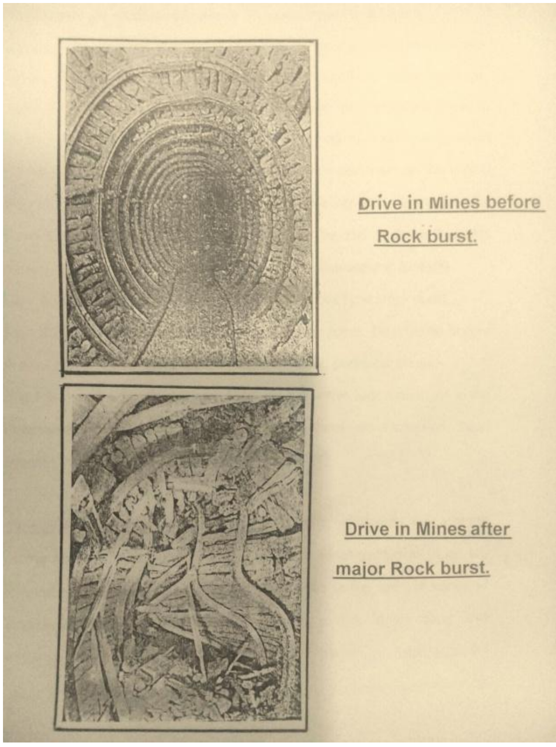

Figure 1: A view of drive in mines before and after the major rock burst

1.3 Study Area

Kolar Gold Fields

The area of the present study is the Kolar Gold field, situated at 12˚57'N and 78˚16'E in the South - East corner of Karnataka state near Bangalore city in India and lies at an altitude of 900m above mean sea level. There is an indication that some of the ancient workings are more than

1,000 years old. However, the Bharat Gold Mines started in 1880 by M/s.John Teylor & sons. Three mines namely the Nundydroog Mine, Champion Reef Mine and Mysore Mine were operating and the workings are spread over a strike length of 8 Km. The problems of ground control and rock bursts have been serious in the mines of Kolar Gold Fields [3] & [4].

Rock bursts have occurred at all depths under different mining conditions. The high strength and brittleness of rock is a main reason for these rock bursts. Whenever rock burst takes place there is an ejection of rock mass from the working site accompanied by explosive noise and followed by a blast. In olden days they mined out the gold and left the void in the underground without back filling and good support. As virgin rock is mined out the natural stability of the rock mass is disturbed then the stress increases beyond the elasticity of rock resulting in the rupture of rocks. This causes rock bursts. However, the problem becomes more serious as mining reached greater depths. One of the mines has reached a depth of over 3.2 Km (Champion Reef).

Rock bursts have caused large-scale damage to underground workings including loss of shafts, traveling and haulage roadways, pumping and winding installations. Surface buildings have also been extensively damaged. Fatalities are generally associated with rock burst. Valuable proved ore reserves have been lost forever. However, the problem of rock burst has been considerably reduced by the introduction of better mining methods, based on studies of rock mechanics [5].

A map of mining areas of Kolar Gold Fields showing Seismogenic features is as shown in Figure 2. There are three significant geologic faults, viz. Mysore North Fault, Tenants fault and Giffords fault, all striking NE-SW. These faults are nothing but plane of weakness in whose vicinity many rock bursts tend to occur. The extraction of the lode is generally done as per standard of metal mining practice. Shafts at depth are usually supported by brick (or) reinforced concrete lining and levels are supported by steel rod sets, lagged and packed.

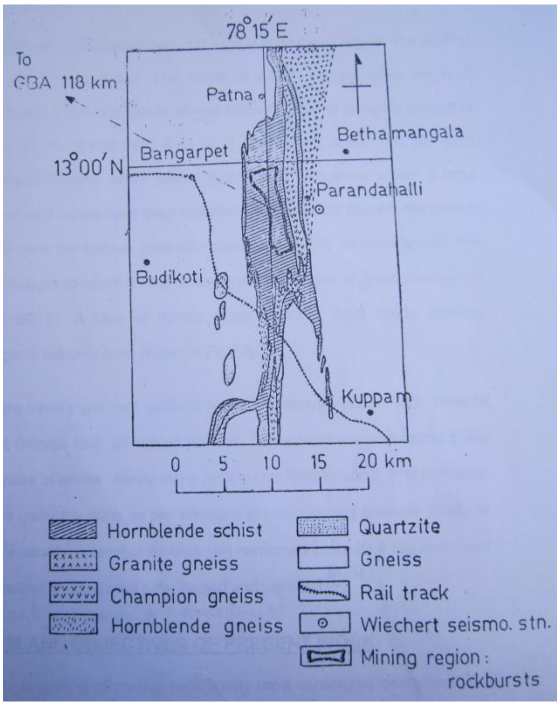

Figure 2: A Geological map of Kolar Gold Fields

Gold mining region of the Kolar Gold Fields (KGF) in Southern India is the second deepest mines in the world. It is known to be confronted with the acute problem of rock bursts that pose hazards to workmen and the destruction of the property both on the surface and underground.

1.4 Aim and Objectives of Present Work

The main objective of this thesis is to locate the epicentre of rock burst in and around the mine, using the single station seismic recorder and to understand the cause and role of old mine workings. After the closure of the mines, the rock bursts are continuing to occur. A single station seismic recorder is being used to monitor the rock burst at present. Epicentres of rock burst are being computed using the single station. In order to understand the phenomenon of rock bursts, ways and means of reducing the frequency and severity of these rock bursts, the seismic investigation was carried out to locate the rock burst that occurs in and around mining station.

2. Literature Survey

The experiences of different mining around the world with regard to rock burst and its problem are necessary which are covered in the literature study.

Germany: The problem of Rock burst was faced in a potash mine situated on the tip of the South German Block, Germany [6]. The conception of seismological mining control consists of a wide array of seismometers whose signals are recorded automatically, if a triggering criterion is fulfilled. Seismic signals are measured on a very wide band. Measures have been taken to prevent the occurrence of a rock burst (or) passive measures to limit the effect of a rock burst in a mine.

U.S.A: Rock bursts in the deep metal mines of the Coeur d"Alene district present an ever increasing problem in the safe and economic mining of the district's silver, lead and zinc ores. Hecla Mining Company operates two mines in the district- The Stroe lead-zinc mine and the Lucky Friday, a silver-lead mine. Rockburst problems at both operations prompted Hecla management to make an all out attempt to find a practical method predicting and eventually controlling these rock bursts [7].

It is difficult to assess the full effect of rock bursting in any given area in this mine. Certainly, damage to structures can be measured, injuries and fatalities can be counted, even lost production estimated, but the most crucial of all may be immeasurable, that could be released without warning.

South Africa: The deepest mine in the world is gold mines in South Africa. Rock bursts that occur in the vicinity of mining activity cause very intense damage to the workings and also cause occasional loss of life. The Witwatersrand gold fields, where the study of rock burst began early in the 20^{th} century [8] & [9]. Currently involve gold production at depths between 2000 & 4000m. In these mines, gold production is achieved by excavating sub horizontal tabular stopes. The high level of rock bursts typically within several hundred meters of the active mine faces, is associated with the substantial stress changes in the brittle strata abutting the stopes. The source of energy for this process is the collapse of the tubular voids due to the considerable overburden [10] & [11].

Australia : In Western Australia ,where an unusually high horizontal stress gradient appears to be a root cause for severe seismicity and rock bursting in several mines, at depths of less than 500 meters. Of particular interest are mines in which the mine seismicity problem gradually evolved from reports of rock noise from underground workers, to occasional large shakes felt throughout the mine, and ultimately to a mine seismicity problem that is pervasive throughout the mine which may threaten the viability of the mine.

India
(a) Zawar Group of Mines: It is about 42 km south-east of Udaipur city and is presently the only major source of the lead-zinc ore in the country. These mines are facing the problems affecting the stability of underground openings in one of the lead-zinc mines (Mochia mines) of this area [12].
(b) Hutti Gold Mines: The Hutti Gold mine is situated in Karnataka has reached a depth of about 700m from the surface and is now facing rock burst problem in one of the stopes under extraction. In addition to mining at depth, presence of faults and dykes accentuate the occurrence of rock burst.

3. Methodology

3.1 Seismic Recording Instrumentation System In K.G.F

Monitoring rock burst tremors to locate their foci and based on seismic activity and obtaining timely warning of an impending danger is a great step forward in minimizing the hazard. A multi-channel seismic network consisting of 14 Geophones (7 surface and 7 underground) was established to cover the mining area of 6 Km x 3 Km. The signals picked up by the sensors are directly transmitted through 4 - core cable using a carrier frequency of 540 hertz, and recorded on a 24 – channel analogue tape recorder at a speed of 15 mm/sec which is shown in Plate- 1. The underground network consist of 10 high frequency geophones accelerometers and the micro-seismic signals picked up by the sensors are telemetered through a 4-core cable and fed to a microprocessor through an interface unit located in the surface laboratory.

Figure 3: Plate-1: Complete view of Seismic Recording Instrumentation

The signals pass through the logic and delay processor of the event threshold detector. The onset of signals of different channels is detected and time delays in a digital form are fed to the micro-processor, which processes the data and prints out the required information on hypocenter parameters. An event counter is also included in the network to count the micro-seismic events in each channel and displayed for a set time to ascertain the rate of micro-seismic activity in the region. The frequency band width covered is 100 to 1,000 cycles.

This instrument has proved a valuable tool in assessing the day-to-day safety of mine workings and on many occasions work has been suspended or resumed depending on the seismic activity recorded from rock burst prone areas. Also Micro-seismic investigations have given positive information in some instances for prediction of rock bursts. This seismic set-up at BGML has provided for the first time in the country valuable data of rock bursts inside the mines, which has greatly helped to achieve better ground control and in problems of mine safety. Apart from this, the network has also provided important data of strong earth tremors occurring in this region. Plate-2 shows recorded Rock burst from Seismic Instrumentation.

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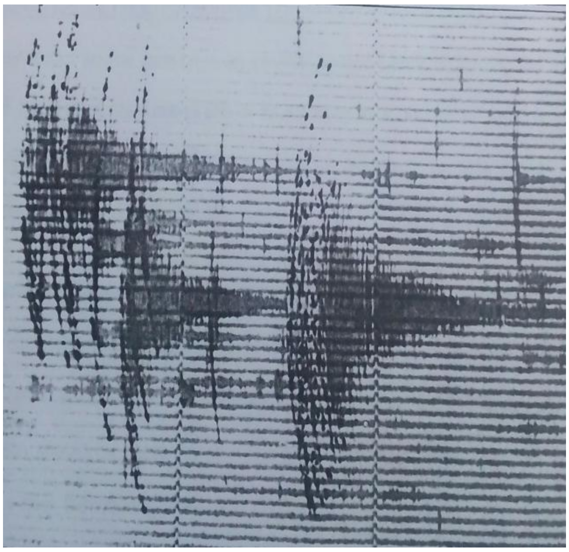

Figure 4: Plate-2: Complete view of Recorded Rock burst using Seismic Instrumentation

3.2 Strong Motion Accelerograph in Kolar Gold Fields

It is a Seismic Data Acquisition system and the accelerometer is internally mounted. This instrument is supplied by GeoSig Ltd., Switzerland. During normal operation the instrument continuously records, amplifies, filters and converts sensor inputs to 18 Bit digital form and passes these to a pre-event memory. When the specified triggering criteria have been met, the instrument begins recording the data from the pre-event memory. The minimum threshold kept in the present case is 0.0003g. With the communication software program running on any IBM Compatible personal computer set up and retrieving of recorded data is performed. Recorded data include the sensor data, clock/timing information and instrument set-up information. Plate-3 shows the Strong Motion Accelerograph instrument.

Figure 5: Plate-3: Complete view of Strong Motion Accelerograph

4. Results and Discussions

The rock bursts were recorded using a network of geophones in the Seismic recording station in around Kolar Gold Fields and the source locations were precisely located in the early days when the mining operation was in full swing as mentioned in this thesis. The seismic recording system became obsolete and discontinued after closure of the mines of Kolar Gold Fields. The rock bursts are continuing to take place even after the closure of the mines. These rock bursts were recorded by single station Strong Motion Accelerograph as shown below.

Magnitude : 2.3 on Richter scale.
Location : North-west Quadrant.
Epicentral Distance : 1.275 Km.

The rock bursts are being recorded at present on the single station Strong Motion Accelerograph. This has three component recordings, namely Vertical component, North-South component and East-West component. When a rock burst is recorded, depending on the source of rock burst each component will record acceleration proportional to the energy from respective direction. From the phase of P-wave whether it is compressional (upward motion) dilatation (down ward motion) in each component one can determine the quadrant from which the rock burst signal has arrived. From the arrival of P-wave and the S-wave the epicentral distance can be computed. Based on the amplitude of P-wave the magnitude can be computed. Thus, using one single station the location of rock burst has been computed.

The single station has some limitation where only epicenter can be computed and the depth cannot be computed. The result is approximate and can be verified in the case of major rock burst where the rock burst results in surface damage. In order to locate the actual source location and assess the stability of mine workings and forewarn the occurrence of damaging rock burst, a network of geophones should be deployed and monitored using the latest seismic monitoring system. Thus the seismic monitoring instrument can be used for different geotechnical areas in general and in particular different mines.

5. Conclusion

The rock burst problem is very common in the mining environment and it posses severe danger, especially when the mining operation reaches a greater depth like the mines of Kolar Gold Fields, South African Gold Mines and other mines all over the world.

Locating the source of rock burst in heterogeneous medium such as mining was difficult in the beginning. However, with the use of latest scientific monitoring instruments, it has become possible to compute the source location using network of geophones deployed in and around the mines like Kolar Gold Fields.After the closure of the century old mines of Kolar Gold Fields, the sophisticated seismic monitoring system was discontinued as it became obsolete. The rock bursts are continuing even after the closure of mines. These rock bursts are being recorded at present using single station recorder.

In the present study the rock bursts recorded by a single station recorder (Strong Motion Accellerograph) have been used to compute the epicenters. The source location rock burst is achieved to meet the objective of the present work. On the other hand, multi channel (network) systems provide the capability to locate the source of individual event precisely and thus the problem area can be delineated for safety and stability purposes.

Many objectives in term of overall stability studies can be undertaken by single station monitoring such as in the present study. The following areas has future for applications.
1) Mining related problem.
2) Storage of oil and gas caverns
3) Nuclear waste disposal sites.
4) Stability of slopes and embankments of dams.
5) Reservoir Induced seismicity.
6) Landslides
7) Estimation of Seismic hazard and Risk.

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