REAL TIME MONITORING OF GROUND VIBRATIONS BY BLASTING IN MINES VIS-A-VIS –A-VIS WSN AND IOT FRAMEWORK

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ABSTRACT

Blasting is one of the most popular and a common technique widely used in quarries and mining production processes. It is the standard industrial cost-effective methodology that provides achievement of expected results quickly in a short period of time with involvement of relatively low cost of expenditure. Usage of Explosive generates ground vibration which is undoubtedly influence on surrounding structure. It is the beneficial industrial technology which provides achievement of expected results in a short period of time with relatively low cost. Never one less, blasts produce undesirable vibrations and sounds. This paper highlights the role of IoT for optimisation of production, profit and safety in the mining industries.The primary focus of presented paper is to develop an internet connected mine monitoring system for ground vibration monitoring due to blasting.

Keywords: IoT, Coal Mine, WSN, Real-Time

INTRODUCTION

Blasting is very important process for mining operation and a lot of explosive is used for this purpose. The blasting process and usage of explosives, however, remain a potential source of numerous human and environmental hazards. Various studies indicate that fragmentation accounts for only 20-30% of the total amount of explosive energy used. Rest of the energy is lost in the form of ground vibration, fly rock, air overpressure and noise. The specific problem associated with ground vibrations represents the human response to them. Blasting vibrations may also cause a significant damage to nearby buildings or various structures. Drilling and blasting combination is still an economical and viable method for rock excavation and displacement in mining as well as in civil construction works. The ill effects of blasting, i.e. ground vibrations, air blasts, fly rocks, back breaks, noises, etc. are unavoidable and cannot be completely eliminated but certainly minimize up to permissible level to avoid damage to the surrounding environment with the existing structures.

Among all the ill effects, ground vibration is major concern to the planners, designers and environmentalists. A number of researchers have suggested various methods to minimize the ground vibration level during the blasting. Ground vibration is directly related to the quantity of explosive used and distance between blast face to monitoring point as well as geological and geotechnical conditions of the rock units in excavation area.The application of proper field controls during all steps of the drilling and blasting operation will help to minimize the adverse impacts of ground vibrations, providing a well-designed blast plan has been engineered. The design would consider the proper hole diameter and pattern that would reflect the efficient utilization and distribution the explosives energy loaded into the blast hole. It would also provide for the appropriate amount of time between adjacent holes in a blast to provide the explosive the optimum level of energy confinement

INTERNATIONAL SCENARIO

In this section we present a review of works carried out by the researchers in international and national context through study of literatures from various sources and presents the review organized into three sections reflecting the international, national and regional status.

Y.L. Guiet al. [1]have designed a numerical model to understand the impact of the attenuation law and the geological features on the blast wave propagation. The field test results are then used to calibrate the numerical model. From the calibration, the parameters involved in the general form of peak particle velocity have been determined. It is demonstrated that the blast wave propagation in the free field is significantly governed by the field geological conditions, especially the interface between rock and soil layers.Li Ma et al. [5] have incorporated Janbu's Limit Equilibrium Method (LEM), pseudo-static methodto analyze the influence of dynamic loads of blasting on slope stability.

NATIONAL SCENARIO

These are the previous research work on different systems using different technologies for ensuring the work-place safety in the mines environment.

Ranjan Kumar et al. [4] have proposed generalized empirical model forPPV which has a good correlation coefficient and hence it can be directly used in prediction of blast-induced vibrations in rocks. The proposed empirical model for PPV has also been compared with the empirical models available for blast vibrations predictions given by other researchers and found to be in good agreement with specific cases. Prashanth Ragam et al. [2] have suggested wireless sensor network to monitor the effect of blast induced vibrations on structures. The paper explains a frame work of the process of monitoring and transferring sensed ground vibration data from a blast site to monitor site while blasting in mines. Mahdi Saadat et al. [3] have proposed an ANN based approach to predict blast-induced ground vibration ofGol-E-Gohar iron ore mine. To demonstrate the supremacy of ANN approach, the same 69 data sets were used forthe prediction of PPV with four common empirical models as well as multiple linear regression (MLR)analysis. The results revealed that the proposed ANN approach performs better than empirical and MLRmodels.

BLASTING PRACTICES AT THE MINE-CASE STUDY

The Dungri limestone mine is fully mechanized mine being operated by drill and blast method for primary breakage and rock breaker for handling of oversize fragments. Fig 1shows a view of blasting in trial blast and working benches at Dunguri mine, ACC. Atlas Copco make D50 and Sandvik make TITON 500 drill machine is being used regular drilling and blasting operation with 9 to 10 m bench height. Burden varied between 3 and 3.5 m, spacing between 4 and 5 m and quantity of charge per hole between 40kg & 60 kg for 115 mm drill diameter. Accordingly, the stemming column in the blast holes also varies between 2.5m to 3.0 m. Holes are drilledin staggered pattern and square grid pattern. The depth of the blast hole is 10 meter including 10% sub grade drilling. The non-electric (NONEL) system of initiation with TrunkLineDelay (TLD) of 17/250ms and 25/250ms are being used for blasting work in combination with ANFO and cast booster weighing 150 gm. In case of watery hole during the rainy season and in the lower bench large diameter slurry explosive cartridge (Aquadyne and Supergel) is used for blasting. Each blast is monitored for ground vibration and fragmentation and necessary care is taken based on the report obtained. Minimate is used for measurement of ground vibration in the mines.

Fig 1: A view of blasting in trial blast and working benches at Dunguri mine, ACC

In blasting, two to three rows of holes are blasted at a time and a maximum of 60 holes are blasted at a timewith proper initiation pattern, charging pattern and charge per delay. Ground vibration is maintained within 3.00mm/s within 300 meter of the blasting site. The top over burden bench is very hard so that the burden is preferred up to 3.5m and spacing preferred up to 4.2 m for the depth of the hole 7m, for 160mm dia of the hole. In the Bauxite burden is preferred to 3.5m and spacing preferred to 4m for good fragmentation for suitable of crusher feed. Staggered drilling patterns are using for efficient blast result.

A sample initiation pattern given below depicts the basting of each hole one after another. General blasting pattern followed in the mine and charging pattern are shown in Figure 2(shows drill hole pattern in the experimental blast site) and Figure 3 (charging pattern being followed), respectively.

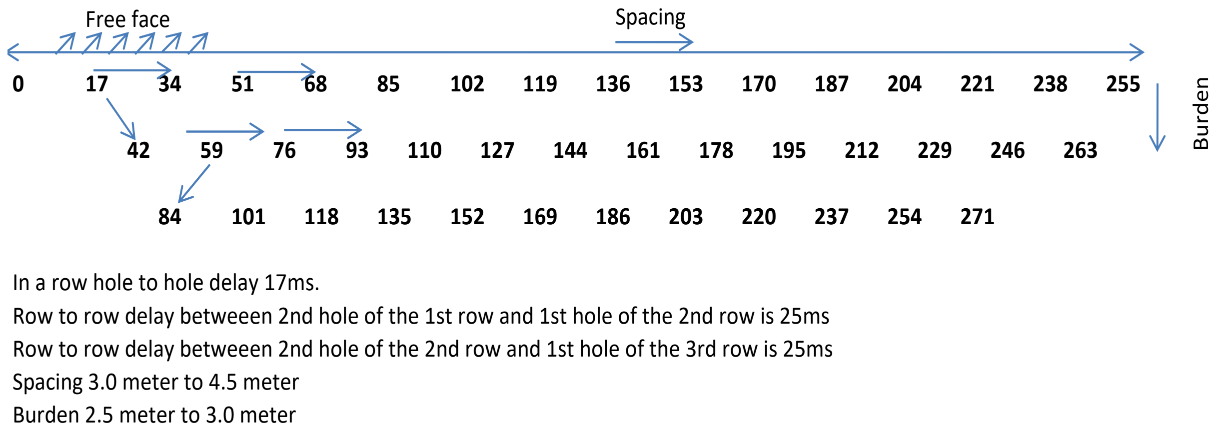

Figure 2: General blasting pattern followed at Dunguri mine, ACC

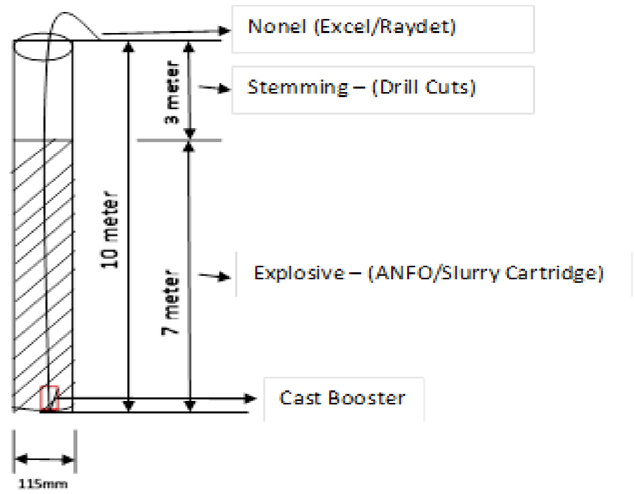

Figure 3: General charging pattern followed at Dunguri mine, ACC

Drilling Operations

IDM 30 Atlas Copco Drilling machine was used for the drilling of the holes; the rate of penetration is 30m per hour in hard, 45m per hour in medium hard strata. Vertical and inclined holes are drilled with this machine. It consists AC cabin so that operator not effected by dust and machine vibration. Twindet 17/ 250 ms, i.e., TLD 17ms and DTH 250 ms are used for controlled blasting to reduce ground vibration and noise.

The TLD delay 17ms for hole to hole in a row and the TLD delay 25 ms for row to row is the best blasting sequence because in this sequence no two holes are overlapped. So that it is giving good fragmentation, less PPV, less noise, less fly rock etc. The increasing of DTH Delay from 250 ms to 450 ms increases number of holes to be blasted in a single phase. Emul booster is using for the initiation of SME @ of 0.4% of SME by weight. These Emul boosters are initiated by DTH (Nonel). Electrical detonators are used to initiate the Soft Tube.

1. Preparation of drilling Front:
   a. Dozer or wheel loaders are using to prepare drilling front to avoid presence of loose boulders on drilling face before commencement of drilling operations.
   b. The leveled surface provides safety to drilling machine while drilling.

2. Marking of the holes:
   a. Drilling supervisors should give proper markings of the drill hole as per instructions of the Blasting officer and Blasting Foreman.
   b. After completion of the drilling operation drilling supervisors should cross check the location of the drill holes with burden, spacing and the depth of the hole.

Blasting Operations

a. As per record of the hole data Blasting Officer should plan the charge per hole.
b. Priming should be done carefully and under the supervision of Blasting Foreman and Blaster.
c. Trained persons should be involved in priming operations.
d. Blasting Officer and Blasting Foreman should monitor charging and stemming operation.
e. Proper sequences of connections should be done by Blaster under the supervision of Blasting Foreman and Blasting Officer. Figure 4, 5 and 6 shows photographs of Emul boost, charging of SME, and performance of blast, respectively.
f. Before commencement of firing, blasting clearance should be taken by Blasting Officer with effective signal system.
g. After firing the shot Blasting Foreman and Blasting Officer should inspect the blasting site for any misfire, if there is no misfire they allow for further operations like loading, hauling etc.,
h. If any misfire occurred they should not allow any other operations unless and until to clear misfire.
i. Blasting officer and Blasting Foreman should maintain bound page book to enter the observation of the blasting, i.e., fragmentation, fly rock,throw, PPV to reduce the charge as required to achieve suitable powder factor.

Figure 4: Emul Boost used for initiation of SME at a typical blast site

Figure 5: Charging of Site Mixed Explosive in the blast hole in a typical Opencast Bauxite mine

Figure 6:Performance of blast with SME at the trial site

Ground Vibration

The movement of any particle in the ground can be described in three ways; displacement, velocity and acceleration. Velocity transducers (geophones) produce a voltage which is proportional the velocity of movement, and can be easily measured and recorded. They are robust and relatively inexpensive and so are most frequently used for monitoring. It has been shown in many studies, most notably by USBM that it is velocity which is most closely related to the onset of damage, and so it is velocity which is almost always measured. If necessary, the velocity recording can be converted to obtain displacement or acceleration. Each trace has a point where the velocity is a maximum (+ve or -ve) and this is known as the Peak Particle Velocity (or PPV) which has units of mm/s.

Waveforms of Blast Vibrations

The ground vibration wave motion consists of different kinds of waves:

- Compression (or P) waves.
- Shear (or S or secondary) waves.
- Rayleigh (or R) waves.

The Compression or P wave is the fastest wave through the ground.The P wave moves radially from the blasthole in all directions at velocities characteristic of the material being travelled through (approximately 2200 m/s).The Shear orS wave travels at approximately 1200 m/s (50% to 60% of the velocity of the P wave).The P waves and S waves are sometimes referred to as ―body waves because they travel through the body of the rock in three dimensions.The Rayleigh or R wave is a surface wave, which fades rapidly with depth and propagates more slowly (750 m/s) than the other two waves.

Parameters influencing propagation and intensity of ground vibration:

The parameters, which exhibit control on the amplitude, frequency and duration of the control vibration, are divided in two groups as follows:

A. Non-controllable parameters

B. Controllable parameters

The Non-controllable parameters are those, over which the blasting engineer does not have any control. The local geology, rock characteristic and distances of the structure from blast site is non-controllable parameters. However, the control on the ground vibrations can be established with the help of controllable parameters. The same have been reproduced below:

- Charge weight
- Delay interval
- Type of explosive
- Direction of blast progression
- Coupling
- Confinement
- Spatial distribution of charges
- Burden, spacing and specification and specific charge

INTERNET OF THINGS

In the Internet of Things (IoT) paradigm, many of the objects around us will be on the internet in one form or another. The IoT is at the heart of this transformation. It connects people, machines, items, and services to streamline the flow of information, enable real-time decisions, and open new opportunities in every sphere of life The “Internet of Things (IoT)” covers a huge range of subjects from embedded operating systems and micro-controllers to wireless protocols.Advances in the areas of embedded systems, computing, and networking are leading to an infrastructure composed of millions of heterogeneous devices. These devices will not simply convey information but process it in transit, connect peer to peer, and form advanced collaborations.

***Method* of implementing IoT in coal mine:**

There are various methods of implementing the platform for IoT in mines. One way is the use of access modes. There are three access modes:

- ***Open Platform Communications Server:*** This is a software program that converts the hardware communication protocol into the OPC protocol. The OPC client uses the OPC server to get data from or send commands to the hardware. The OPC helps with onsite process control by exchanging real time data
- ***Database access mode:*** various databases including the configuration software of IoT, ground control and manual control systems have connection interfaces which make exchange of information above the ground and underground easy.
- ***Ethernet access model:*** Mines mainly use RS485, 422 and CAN highways whose data procuring capability is low and strength is less. An Ethernet model can cover all these shortcomings by transferring the realtime data into a compatible industry al Ethernet protocol and then this data is processed by acquisition server for big data analysis and safer working of mine.

WIRELESS SENSOR NETWORK IN IOT FRAME WORK

Wireless Sensor Networks (WSNs) are a new kind of *ad hoc* network, which consist of hundreds to thousands of WSN Nodes that communicate with each other, and can monitor areas from small to huge [9]. WSNs have emerged as a powerful technology. In recent years, with the rapid development of mobile communication, micro-electro-mechanical-systems (MEMS) and high-speed electronic devices, sensors with characteristics of low power consumption, programmability, multi-parameter sensing or multi-sensor modules and low power consuming wireless communication infrastructure have provided practical wireless solution to real-life problems in variety of domains. With outstanding advantages of ease of configuration, flexibility to shrink or expand the monitoring range, strong fault-tolerance and mobility, WSNs can play an important role in monitoring and analyzing dynamic, hostile and unfamiliar environments. Conceptual structure of a typical WSN is shown in Fig-7 below.

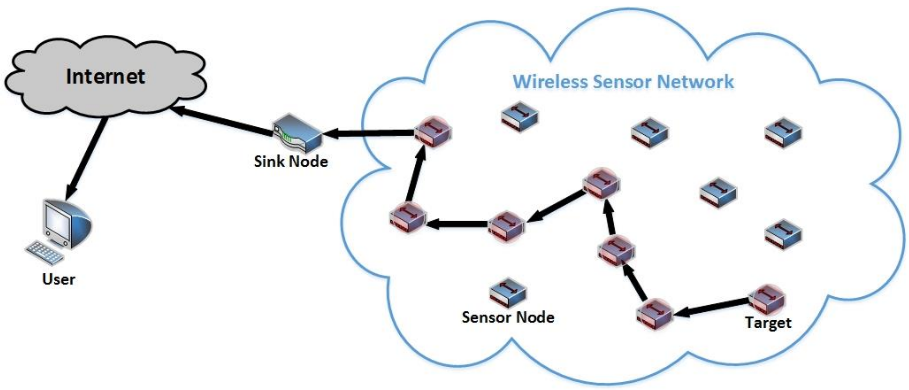

Fig-7: Conceptual Structure of a Wireless Sensor Networks (WSN)

The wireless sensor is characterized by low power and long operation. It sends out data via the communication components at the node. The communication among various nodes in the environment forms a small network, and the sensed data can be transferred on the optimum data transmission path in this network environment.
There are several key components that make up a typical wireless sensor network (WSN) device shown in Fig. 3.

1. *Low-power embedded processor:*

The computational tasks on a WSN deviceinclude the processing of both locally sensed information as well as information communicated by other sensors.

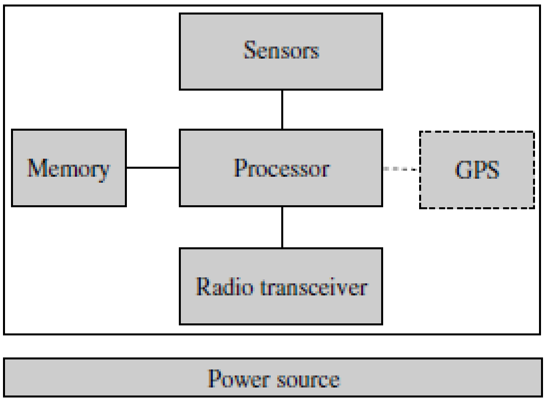

Fig: 3 Basic building blocks of a sensor node.

The embedded processors are often significantly constrained in terms of computational power (*e.g.*, many of the devices used currently in research and development have only an eight-bit 16-MHz processor). Due to the constraints of such processors, devices typically run specialized component-based embedded operating systems, such as Tiny OS.

2. *Memory/Storage:*

Storage in the form of random access and read-only memoryincludes both program memory (from which instructions are executedby the processor), and data memory (for storing raw and processed sensormeasurements and other local information). The quantities of memory andstorage on board a WSN device are often limited primarily by economicconsiderations, and are also likely to improve over time.

3. *Radio Transceiver:*

WSN devices include a low-rate, short-range wirelessradio (10–100 kbps, <100 m). While currently quite limited in capability too,these radios are likely to improve in sophistication over timeincludingimprovements in cost, spectral efficiency, tunability, and immunity to noise,fading, and interference. Radio communication is often the most powerintensive Operation in a WSN device, and hence the radio must incorporateenergy-efficient sleep and wake-up modes.

4. *Sensors:*

Due to bandwidth and power constraints, WSN devices primarilysupport only low-data-rate sensing. Many applications call for multi-modalsensing, so each device may have several sensors on board. The specific sensors used are highly dependent on the application; for example, they mayinclude temperature sensors, light sensors, humidity sensors, pressure sensors,accelerometers, magnetometers, chemical sensors, acoustic sensors, or evenlow-resolution imagers.

5. *Geo-Positioning System:*

In many WSN applications, it is important for allsensor measurements to be location stamped. The simplest way to obtainpositioning is to pre-configure sensor locations at deployment, but this mayonly be feasible in limited deployments. Particularly for outdoor operations,when the network is deployed in an ad hoc manner, such information is mosteasily obtained via satellite-based GPS. However, even in such applications, only a fraction of the nodes may be equipped with GPS capability, due toenvironmental and economic constraints. In this case, other nodes must obtaintheir locations indirectly through network localization algorithms.

PROPOSED WORK

IoT BASED MULTI-SENSOR WIRELESS MONITORING SYSTEM

An attempt is made at a typical underground mine to investigate the effect of blast vibration critical regions and their effects on surrounding structures which can be extended for monitoring of far distance buildings. A real time monitoring system using wireless sensor network in IoT framework, which includes multiple sensors, is developed. Sensor networks are crucial components of many applications as the data they gather are fundamental for the services. Wireless sensor networks (WSNs) are especially important as they can be built by relatively cheap and small sensors with low power consumption and maintenance cost whose ability to transmit data remotely allows their deployment at a large variety of locations [6]. Multi Sensor Network is nothing but the Network created by the sensors which will be connected to a controller. The controller reads the data of all the sensors. Each sensor has a unique Identity or the address so that the controller will identify which data belong to which sensor location-wise [7]. A multi-sensor arrangement will help provide an exact data map of specific application area with respect to the specific parameter being sensed without sacrificing the homogeneity of readings. In contrast, a single sensor approach to gather data at different geographical points will produce only an approximation of the map through the data being collected from uncorrelated events producing heterogeneous readings.

A WSN with IoT framework consisting of multiple sensor nodes that are connected wirelessly to a sink node (central node) is shown below in Figure 11. Kim *et al*. developed a vibrating wire WSN to monitor the tunnel construction with ZigBee protocol [8].The proposed system suggested in the paper is equipped with a 3-axis acceleration sensor, an A/D converter, Atmega microcontroller and ZigBee-based communication system,Figure7. The sensor module forms part of a Zigbee based wireless sensor network having an XBee radio in the PCB on-board so that the data can be wirelessly received and transmitted among each other.

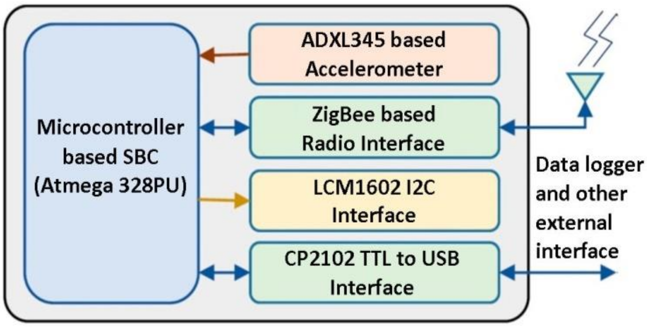

Fig 4:3-axis Accelerometer node in the development of a WSN based monitoring system

CONCLUSION

Vibration monitoring can ascertain motion levels of natural as well as seismic activity. Many investigations were conducted over decades for prediction of strata movement in underground mines with wired sensor systems. Most of the time these systems were associated with problems related to disconnection of wires in mines. IoT is one of the latest technological ventures of this generation. It helps in ensuring safe and proper working conditions and also helps in the growth of economy of a country. IoT is considered as a global network infrastructure devices that rely on sensors, communication, networking and information processing technologies providing benefits like high productivity, safety, asset management, connected logistics, real-time alerts etc. Low-cost wireless sensor network by zigbee technology is a feasible alternative to conventional sensor like blast mate-III, minimate and minimateplus to monitor blast induced ground vibration. Hence, there is a driving force for implementation of WSN systems in underground mines for better monitoring of ground behaviour without getting affected by mine hazards such as fires, roof falls etc.

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