CHALLENGES FOR IMPLEMENTING ADVANCED BLASTING TECHNOLOGY IN INDIA

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Abstract

With the development of new explosives systems and initiation devices, blast design and execution techniques, the blasting process has now become more efficient and safer than before. The innovative practices in the area of drilling, new bulk loading of explosives & initiation systems, performance measurement and the evaluation of blast outcome and productivity need to be adopted in Indian mines. Blasting operations cause several adverse environmental effects and may result in safety problems. This paper gives examples of predicted parameters and changes which can be made before blasting to control adverse environmental impacts.

1. Introduction

Indian mining industry is poised for some exciting opportunities and challenges. The development, advancement and utilization of the innovative technologies are very important for the mining industry to be cost effective and globally competitive. It has been realized that the unit operations such as drilling, blasting, loading, hauling and crushing are interrelated variables in the total cost equation.

Traditional blasting practices and techniques being adopted in most Indian mines are unable to improve efficiency of drilling & blasting operations and mitigate environmental hazards. One of the reasons for hindering improved mining efficiency is poor blasting practices. There are many examples, throughout the mining industry where due to lack of efficient drilling and effective blasting, mines are not operating at their optimum – in terms of overall production costs, energy utilization, resource management and rock stability whilst, at times, jeopardizing safety or creating an adverse environmental impact. With an increased focus on cost reduction and improved operational efficiency in the mining sector, drilling & blasting operations are globally being conducted through a technology driven optimization process and environmentally acceptable results. Mining companies recognize the need to improve analysis of site data, select appropriate tools and technologies, achieve higher fragmentation and improve exclusion zone management.

Blasting operations cause several adverse environmental effects and may result in safety problems. With the development of new explosives systems and initiation devices, blast design

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and execution techniques, the blasting process has now become more efficient and safer than before. Use of software tools for blast design, support in execution, blast monitoring and analysis makes it possible that damages and dangers from blasting can be predicted before blasting and remedial steps can be taken.

The objective of this paper is to provide details of advanced blasting technology which could be adopted for efficient, safety and controlling adverse environmental controls in blasting operations in India.

2. Current Status of Blasting in India

There are many good examples of blasting operations, however general blasts in Indian surface mines are small sized, resulting in frequent blasting, poorer fragmentation and poor utilization of equipment. During the last decade increased use of Shock **Tube/Signal Tube initiation** for down hole initiation has allowed bigger blasts and much safer blasting operations. This technology is catching up in mines; however, many operations are still using detonating cord which results in inefficient blasts and airblast complaints. Some mines have trialed electronic detonators also.

Poor face assessment often, lead to poor yield, wasted explosive and drilling time. Failure to consider and measure the effect of drilling errors render good face assessment worthless, as drilling errors have the same effect as poor burden estimation with the added danger of boreholes encroaching too close to neighboring hole positions. The causes of above errors are: failure to measure actual face inclination, incorrect setting of drilling angle or hole deviation due to geological problems.

Inadequate control of ground and air vibrations and flyrock leads to complaints and agitations. In India, often huge amount of compensation is paid for relocation of villages which are located in close vicinity of mines. However, due to improper control on the ground vibrations, airblasts and flyrock, relocation does not reduce complaints and still results in poor image of mining. Mines are resorting to smaller blasts to overcome the vibration and noise hazards, flyrock and dust. This leads to poorer blasting results, reduced equipment productivity, more manpower requirement and more complaints from neighbors. Further, Indian regulatory requirements regarding ground vibrations (DGMS (Tech) (S&T) Circular No. 7 of 1997) is at times causing immense hardship to mining operations. Mines and consultants pay attention to ground vibrations by charge per delay. But they do not pay attention to airblast and resulting complaints. Figure 1 shows that measurements by mining personnel and even by scientific personnel show inappropriate ways of placing geophone and neglecting airblast measurements. Problem is that regulations insist that scientific institutions only carryout measurements, though all scientists are not fully trained. Perhaps all those who carry out investigations need to be trained. There are several instances that courts have disregarded reports. Airblast overpressure limits have not been prescribed in India. Wave reinforcement resulting in greater vibrations for blasts planned according to charge per delay has been cause of complaints. However, it is important to predict and alter the ground vibration values by using appropriate delays and initiation pattern to remain within prescribed limits.

	
Monitoring of ground vibration and air overpressure at Pit-2 (old dump heap towards Amarpura village) (As given in report of a scientific organization)	Vibration measurements were not appropriately carried out. **The geophone needs to be placed on solid ground. This is incorrect way of placing geophone.**

Figure1 Two examples of inappropriate way of measurements

A standardized procedure is important so that results are comparable. Analysis using software after drilling if carried out can help in recognizing problems of reinforcement thus allowing change in delay timing and sequence before blasting to avoid reinforcement.

In underground mines, often poor rock is blamed for high fatalities due to fall of roof whereas blasting is often a cause of damage to roof, though it can be controlled by appropriate techniques and products. Similar effects are noticed when controlling slope stability effects.

Charging appropriate quality and quantity of explosive and using appropriate initiating system is important. Improper initiation timing is an important reason for not being able to control blasting results. Analytical methods are often not used to identify the problem areas in blast design and explosive performance parameters are measured only in exceptional cases. Blast design in Indian mines uses the method of trial and error to a large extent with some exceptions. Flyrock incidents are often not controlled. This is because appropriate first row design is not considered and appropriate initiation systems and timing are not used. Appropriate stemming material is not used. Uneven burden, inadequate face movements, heaving, back break etc. are some factors which lead to poor performance of blast. Front row burden variation cause poor fragmentation and release of explosive energy. The charge in the holes of first row should be based on profile of the face.

Blast records where maintained, are inadequate for analysis. Blast records are needed to be stored in a systematic way so that it can guide present and future blasting operations. The challenge before the mining industry is to make changes in the presently used blasting technology.

3. Advanced Tools and Techniques

With the development of new explosives systems and initiation devices, blast design and execution software tools, the blasting process has now become more efficient and safer. Blasting operations are utilizing technology systems that underpin rock blasting in open pit and underground mine operations, such as predictive modelling, blast design, radio-controlled detonation, real-time monitoring of drilling, charging and post-blast data analysis. Information Technology (IT) systems are being used to record, manage and analyse data being generated. Developments in information technology have gone through leaps and bounds, which have led to ripple effects in raising the standards of technology in drilling and blasting. Several tools can be used in assessing blast face conditions, assist in designing blast, executing blasts, during and after blast monitoring, recording all results and analysing records. Information must be collected during drilling about the rock strata so that loading pattern of blast holes can be decided. Many tools and techniques have taken the guesswork out of explosives loading and blasting operations (Rodgers, 1999). Some of them are:

Face profiler systems using laser technology profiles the rock face by pointing profiler to the floor, toe and crest – then take accurate measurements and calculates bench heights, minimum and optimum burdens, computes drill hole angles and offsets, and hole depths. Drills may have a tendency to follow the faults, weakness planes, weak rock, cavity or similar other geological weakness creating borehole deviation.

Hole Deviation measurement tools, operators discover light burden areas and are able to thwart safety issues. The cable deviation measurement tools uses sensors that measure borehole deviation at fixed intervals from the collar position and transmit the findings instantly to a field computer.

Another tool is the **3-D laser profiling system**, which includes equipment and software that allows the user to make precise burden measurements without venturing near the crest of the bench. This system, too, transmits its findings instantly to a field computer. From these field computers, the data from both tools are merged in blast design software to adjust the blasting plan by compensating for any initial "guesstimation" of the burden and for drilling inaccuracy.

Another technology that has great importance for drilling accuracy, and the integration of drilling and blasting operations is **Global Positioning System (GPS)** as applied to drill positioning on individual blast holes. New GPS-enabled applications help drill and blast engineers develop more appropriate and more suitable blast designs. Engineers can create designs in the office and upload them to the drill rigs by remote means; drillers can see the patterns from their drill rigs as sent by drill and blast engineers from the offices. Engineers can monitor and follow up drilling progress in real-time from the offices, from any location, depending on how they are connected.

The most significant changes in blast technology have taken place in **explosive-delivery systems.** One factor is the continuing trend away from the use of cartridge products in favor of bulk products for both surface and underground operations: new surface and underground delivery-vehicle technologies that boost blast accuracy and safety: high-precision pumps and blending and measurement devices, robotic arms that place the product in the hole, and remote controls. When considering blasting technologies, operating companies tend to be highly cost conscious, which mitigates opportunities to develop value-added or innovative products.

Electronic detonators are now commercially available. Advantages include more- precise delay timing (resulting in increased blast efficiency and control) and greater compatibility with remote-controlled loading of explosives and wireless detonation. However, these initiating systems have higher costs and trials have given some issues of some manufacturers in watery holes and in underground operations.

4. Blast Execution, Monitoring and Control

Blast should be executed and monitored meticulously. The measurements which can be used to improve blasting execution include:

Pre-blast: Face profiling to better calculate actual burdens at all points on rock face, geology and rock properties, blasthole logging of rock properties, blasthole audits (accuracy of drilling), explosive verification, down hole product densities/pressures. Pre-blast monitoring should also be done cautiously to check deviation in the values of design parameters from the actual ones (Rodgers, 1999). All details like hole position, hole depths, nature and condition of holes, type and quantity of explosives; initiation system, sequence and delay timings are to be recorded. Prior to the introduction of new methods & technologies as working tools in mines, it was not possible to directly measure to inaccessible locations on rock faces. Commonly Used Blasting Instrumentation for Pre-Blast field conditions and geometry:

- Auto scanning lasers (profiling, geometric conditions, volumetric control)
- GNSS (drilling layout, volumetrics)
- Drilling deviation measurement (Boretrak)
- Down hole cameras (voids, cracks)

During the blast

High speed photography / videography, timings (initiation, time to first movement, stemming ejection, flyrock movement), velocity of detonation, face velocities, flyrock, airblast, ground vibration. Commonly used blasting instrumentation during the blast:

- Continuous VOD measurements (explosive and primer performance, timing measurements)
- Seismographs (vibration and air blast analysis) continuous recording GPS included (Figure 2)
- High speed and regular video, still photography (identification of sources of problems from face and surface motion)

Figure 2 Continuous Monitoring Blast Vibration meter with GPS included

Post blast:

It is important to maintain the post blast performance details, site information such as geology, geometrical information of blast site and detailed parameters. Along with that blast performance zone wise, explosive and accessories used and also the unusual happenings should be recorded for further references. The evaluation of blasting results indicates whether they are satisfactory or not and thereby help in correlating the design parameters with actual results.

The fields of applications of new technologies can be listed: muck pile profiling to determine throw, cast blasting, muck-pile models to determine swell & blasting effectiveness, rock pile characteristics (distribution/swelling), induced cracks and over breaks (rock damage at blast limits) fragmentation /size distribution; oversize/fine assessment, loading performance, crusher performance, field conditions and geometry, fumes and flyrock.

Commonly used blasting instrumentation for Post-Blast results:

- Auto scanning lasers (muckpile profiling, geometric conditions, volumetric control)
- Photo fragmentation analysis (Wipfrag, Split, Fraglyst)
- Photography

The field monitoring and controls, if properly used, can be valuable tools in the optimization of blasts. If the field control is poor and implementation of the design is improper, even an optimized design will not produce desired results.

5. Blast Design, Record and Prediction Software

Optimum blasting just does not happen. It requires suitable planning, good blast design, accurate drilling, the correct choice of explosives and initiation system and methods, adequate supervision and considerable attention to detail. The rock type and structure; size, length and inclination of blast holes, drilling pattern and accuracy, type, quantity and distribution of explosives; charging and initiating techniques all play a significant role in the overall efficiency of a mining operation. During the design stage environmental constraints such as vibration limits or flyrock restriction with respect to any structure can be prescribed. Blast design software (Figure 3) can be used which considers all the above aspects. A mine can be set up in one of two ways; either the plant is set up to accept whatever fragmentation the blasting group produces, or the plant dictates to the mining teams the fragmentation distribution they will accept. Designer can include fragmentation prediction in this software.

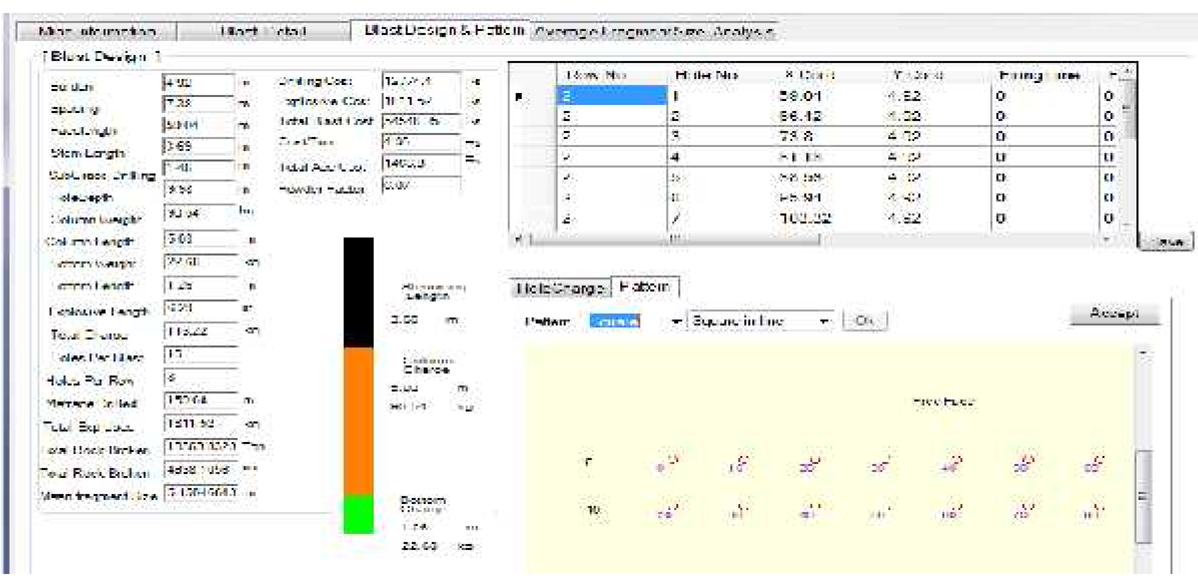


Figure 3 Blast Design Software (BLADES)

Figure 4 Blast Information Management System (BIMS)

Routine mine blast operations experience must be gathered and stored in a systematic way so that it can guide present and future design changes. Blasting information management software (Figure 4) and measurement techniques can be used to monitor, access and analyze the blasting performance so that appropriate modifications can be made to design the optimum blast (Bhandari 2011).

Regular feedback is required to ensure that the blasting objectives are routinely achieved, and if not, to determine what aspect of the process requires attention. Apart from special investigative blast monitoring, routine blast audits are necessary to check implementation of blast designs on the field. Blasting audit should be carried out to monitor blast execution and performance and then quantify blast results. Photographs and Video analysis in slow motion helps in analyzing blasts.

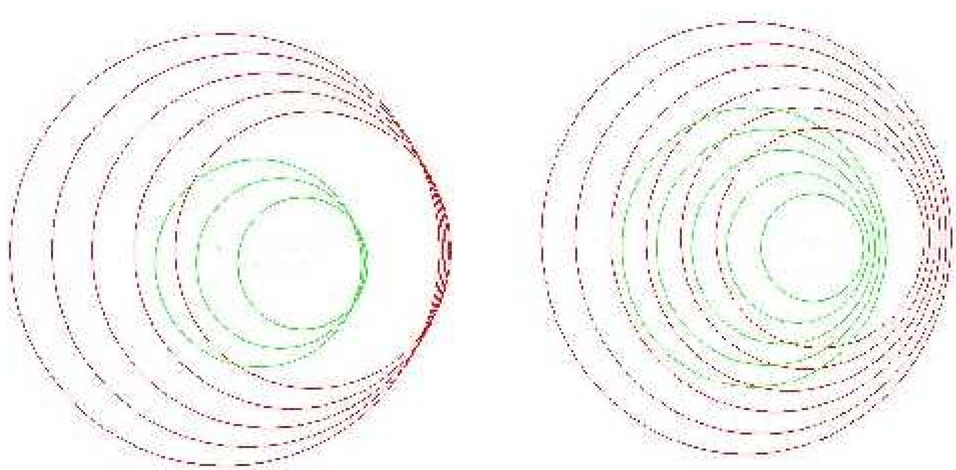
6. Environmental Hazards, Prediction and Control

Increasing numbers of mining operations are coming under pressure to monitor and reduce blasting related safety and environmental hazards. Ground vibrations, air over-pressure, fly-rock, dust, blasting fumes in some cases leaching of chemicals in the blast holes and polluting ground water are some of the undesired events associated with blasting which collectively affect the surrounding environment adversely.

Much work has been carried out on the environmental aspects such as ground vibration and airblast control (Richards and Moore, 1995). Operators are now aware about the steps which need to be taken. Norms and standards regarding ground vibration and air blast as specified by regulating agencies must be complied with. It is therefore, vital for the industry to do all that it can to reduce the vibration levels experienced at these adjacent properties without imperiling the financial viability of the enterprise. In one case a review of seismograph readings showed that vibration levels at neighbors were low up to 2mm per second, as expected, but air blast levels exceeded significantly and appeared to be the source of complaints.

As the frequencies of ground vibration for coal, lignite and iron ore mines are usually lower than 8 Hz, the permissible PPV as per the current regulation is 5 mm/s for residential structures that do not belong to the mines. Iron ore mines, which are usually located away from villages and townships, can comply with this limit without much problem. However, the imposed limit severely restricts the blasting operation in coal and lignite mines. The limestone quarries and construction projects are in a relatively better position, as frequencies are greater than 10 Hz for which permissible PPV is 10 mm/s. If the frequency below 8 Hz can be shifted to higher ones, then higher PPV is permissible as per the existing vibration standard. As the frequency of ground vibration is difficult to alter, PPV has to be controlled within the specified level at the distance of concern. Due to the sprawl of dwellings around surface coal mines and the stringent statutory limits to be complied with, the mining industry has adopted various control measures. These measures have cut down the profit margins of most mines and put question marks for survival of some mines (Adhikari, 1999).

Blasting operations can generate large quantities of **dust**. This dust when released in an uncontrolled manner, can cause widespread nuisance and potential health concerns for on-site personnel and surrounding communities. Though the blasting dust plume is raised for few minutes but most of the dust settles in and around mining area and some of it is dispersed before settling down. Depending on meteorological conditions the dust dispersal can travel to substantial distances endangering health of communities. Generation of fines and dust is influenced by several blasting and rock parameters (Kumar and Bhandari, 2001, 2002)



A B

Figure 5 Wave Reinforcement in A can be changed to no reinforcement in B by changed delay

However, production of fines and dust need to be reduced and controlled for better environmental conditions (Hagan, 1979). Dust generation and dispersion from blasting operations depends on factors such as meteorology, bench height, blast design information, and rock. (Bhandari et al, 2004). Concern is expressed about nitrogen-oxide (NOx) releases from blast sites and their potential health impacts on workers, as well as their aesthetic and environmental impacts on nearby communities.

7. Safety

Explosives handling and blasting operations are high consequence risk activities. There are many safety hazards associated with use of explosive, transport and storage. One of the safety hazards during blasting is flyrock. Damage due to flyrock from blasting is one of the main causes of strained relations between mining operation and neighbors. Flyrock distances can range from zero for a well controlled mine blast to nearly 1.5 km for a poorly confined large, hard rock mine blast and many fatalities have occurred. In a circular, The Director General of Mines Safety India in 1982 had recommended that personnel be removed up to 500 m, though previous limit was 300m only. Thus, where large diameter blasting is carried in hard rock mining, extra precautions are required to control the flyrock damages in the surroundings. There is a 'safe' blasting area in blasting is dependent on the knowledge of distance to which flyrock will propel. Use flyrock predictor before charging may help in controlling flyrock by altering charging in a hole with reduced burden (Figure 6)

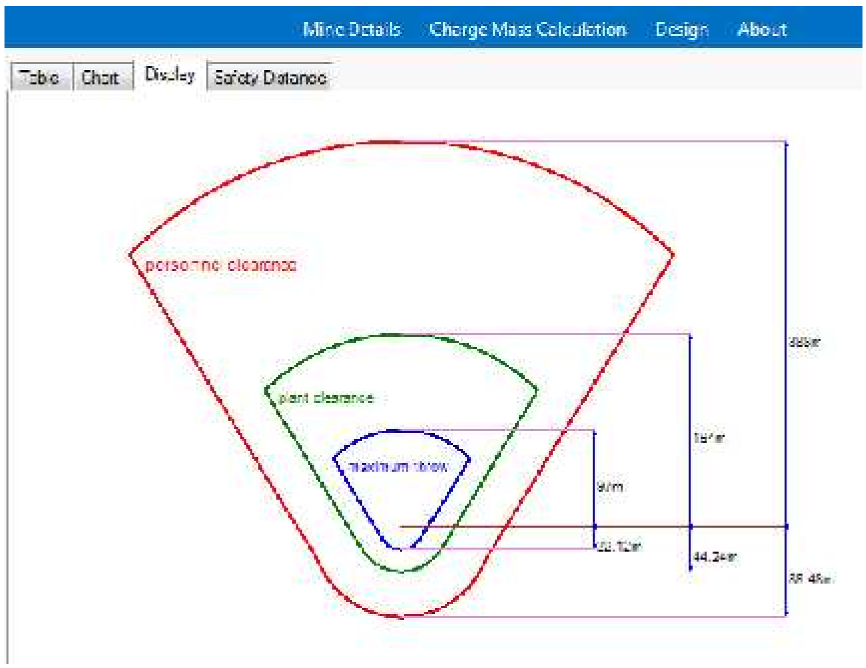


Figure 6 Flyrock Prediction based on blast parameters, explosive distribution and rock

8. Skill Development

If scientifically designed blasts are to be properly executed then drilling and blasting personnel need to be trained. Drillers need to provide detailed logging of all drill holes and they are educated about reporting of any anomalies. Explosive loaders (blaster and bulk truck loaders and helpers) need to be educated about the requirements of each shot, including the re-drilling and decking of weak sections.

A problem which exists with the Indian mining industry is not enough emphasis is given on appropriate training in new methods and technology of blasting. The training is imparted by vocational training centers some of them may be using modern way of imparting training but majority are ill equipped and instructors are not trained in the modern techniques. Efforts are needed to develop trainers who are well versed in new techniques. Further, retraining in blasting technology is needed every three years for blasters, supervisors, designers, planners and executing personnel. Regulators need to be kept abreast of what is happening in the technology to ensure reduced risk and improved safety.

9. Conclusions

The challenge before the mining industry is to make changes in the presently used blasting technology. The developments in the areas of planning and design of blasts, drill monitoring, drill hole deviation, laser profiling systems need to be adopted. The innovative practices in the area of drilling, new bulk loading of explosives & initiation systems, performance measurement and the evaluation of blast outcome and productivity need to be adopted. Steps are needed to reduce generation of fines and dust from blasting operations, predict and control ground vibrations, airblast overpressure and flyrock. Blast information need to be available online for easy retrieval and analysis. Indigenously developed computer aided design and analysis tools, need to be adopted for predicting and mitigating blasting hazards. Use of software tools for blast design, support in execution, blast monitoring and analysis makes it possible that damages and dangers from blasting can be predicted before blasting. These adverse impacts of blasting can be controlled and reduced. Prediction tools can be used before carrying out blasts to control environmental impacts and follow safety norms. In mines abroad, it is common to encounter laser measurement technologies, global positioning system (GPS), communication technology and use of digital systems.

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