Electronic detonators: A tool for mitigating mining costs and risks

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***Abstract*—Mining is a hazardous activity and capital intensive in nature too. The cost of stoppage of mines, for any reason, for few hours is enormous. The mines need to minimise the stoppage times to improve productivity and to reduce costs. Mining companies should have to go for large size blasts to achieve this objective. Large size blasts using traditional initiating devices, create numerous concerns to mine authorities like ground vibrations, slope stability, noise, fly rock, back break etc. To extract minerals from earth's crust by opencast method, we break and remove large volumes of waste rock. With increase in stripping ratios in Open Cast method of mining, the waste volumes to be broken for removal is increasing year on year. As the handling of waste volumes increase, the risks associated with mining also increases as the number of blasting events increase, more issues arise on slope stability, control of ground vibrations and noise to permissible limits etc., Blasting productivity and control is mainly governed by delay times used. The delay times proposed to be used should have a wide range (1-10000 MS) and accurate. Otherwise, the blast control becomes impossible, particularly when the charges used per hole are large to very large, and the number of holes to be fired / blast are more than 50 numbers. The team at GOCL demonstrated, that the mining costs and risks can be reduced using electronic detonators at few mines.**

Keywords—Electronic detonators; vibration; waste volume; stoppage time; productivity.

I. Mining and Rock Mechanics

Mining means safe and faster removal of minerals embedded in rocks lying in the earth's crust. Mining therefore means handling rocks safely and efficiently. A good understanding and appreciation of "Principles of rock engineering" is a imperative need, for all technical persons working in mines. Without the right appreciation of rock engineering principles, the technical persons working in mining, cannot mitigate / reduce the risks associated with rock breaking, rock handling, bench slope stability, maintenance of rock dumps, pillar stability, stope stability and roof stability.

II. Mining Scenario in India

Mining minerals from opencast mines is growing more complex year on year in India. More than 90% of mines are using blasting as a means for sizing rocks for their removal. Today only a few coal mines are operating at higher stripping ratios (1:6), like OC mines in Singrauli area and at Ramagundam area. Similarly, today only few mines are operating at depths of plus 200 meters namely SCCL-RG-OC2, HCL-Malanjkhand and HZL-RA mines [1].

Many OC mines are planning to extract minerals by opencast mines up-to a depth of plus 300 meters and with higher stripping ratio's. In the coming years, many new coal mines are envisaged to have higher stripping ratios like 1: 6, meaning more overburden rocks need to be handled. Projections of demand for coal by 2020 is envisaged at 1000 Million tons, and for the over burden removal is around 3000 million cum. To handle increased tonnages of minerals, the companies operating large OC mines, may opt for very large size HEMM, thus incurring large capital expenditure.

Thus, the waste rock extraction is going to increase many times from today. This directly means blasting needs are increasing many fold and the need to conduct large size blasts is also increasing each day. The associated issues related to rock blasting also thereby are increasing, raising concerns of mine safety, mining risks, and associated costs due to stoppages.

III. Key Mining Issues of Large Capacity OC Mines

- The capital costs are going to be high in large OC mines (Rs 5000-20000 million), deploying higher capacity HEMM, and thus the mine stoppage cost per hour or idling cost per hour is going to be large in value.
- It is estimated to be around 0.1- 0.5 million per hour
- Sizing extremely large quantity of rocks, by blasting, in a faster and safer way, throughout the project life cycle
- Ground vibrations, Air-blast, Fly rock, Back break etc., should always be in designed limits
- Maintaining bench slopes, bench widths throughout project life cycle. This aspect is more relevant where the pit width available is less and depth of operation is high.
- Bench Slopes shouldn't collapse even though they are subjected to stresses repeatedly caused by blasting, by vehicular movement, by weather conditions etc.,
- Operating at maximum possible (higher) dump heights and maintaining dumps, more particularly where there is constraint on the mine lease areas

- Dumps need to be maintained in limited spaces available till they are use for reclamation

IV. Mining and Rock Breaking

The complex process of rock breakage process can be defined in a simplified way. All blast design principles are taken care when we define the process as "Explosive energy distribution (in blast block and drill hole), energy confinement for a given time, and energy release after a given time". Many of the mines today, are facing serious difficulties on energy release front, due to inadequate range of delay times and accuracy of them. Understanding rock engineering principles is mandatory for conducting of efficient and safe blasts

As the excavation needs of a mine increases, rock breaking needs increase in direct proportion. Accordingly blast size increases, Number of holes /blast increase, No. of rows/blast increase, making it more complex. Excavation needs are normally governed by capacity of excavator deployed in a mine.

A small excavator of 3.0 cum bucket capacity, may needs to handle 100-120 cum /hr and 1800-2000 cum /day and around 50000-60000 cum per month in a coal mine. Considering a minimum 7 days of blasted material inventory for an excavator, blast size goes to 12600 -14000 Cum. The volume per hole ranging from 80 – 100 Cum, the number of holes per blast may be around 140 -175.

If the excavator bucket size is 10 Cum, it may need to handle 350-400 cum/hr, 6300-7200 cum /day, and 180000-200000 lakh cum per month in a coal mine. Considering a minimum 7 days of blasted material inventory for an excavator, blast size goes to 44100-50000 Cum. The volume per hole ranging from 420 – 640 Cum, the number of holes per blast may be around 78-120.

V. Mining Safety, Costs and Risks

Mining being a HAZARDOUS profession, maintaining safe operations becomes a paramount importance., Safety comes before production and costs in mining. An unsafe operation in mines, add costs to mines in a large way. occurrence of any mining accident causes stoppage of work for few hours to few days. Generally, the causes for accident are investigated fully, before re-starting mining operations. Mining professionals, world-over found that, a well fragmented rock, can result into improvement safety and reduced mining costs. Thus, fragmentation of a blast plays an important role in mining. Mining professional's world-over found that, energy factor also (explosive energy per ton of rock- Kcals/ T) plays a significant role in fragmentation.

Environmental issues like ground vibrations, Air blast, Fly-rock play a significant role in OC mining and its costs in India. Unlike western countries, in India, mining leases are not isolated fully from habitation. The lease areas granted are also short in acreages, then required. This puts an enormous responsibility on mining companies for maintaining environmental issues.

For better appreciation of the environmental concerns of operating mines, based on distances of nearest habitations / public utilities from mine boundary we may categorize them in to three categories, as follows

- Cat-1 – Closest habitation or public utility exists around 700m. ex., The coal fields located near Singrauli, Ramagundam, Manuguru areas nd iron ore mines
- Cat-2 – Closest habitation or public utility exists around 300m ex., The Coal fields located near orba, Talcher, Raigarh, and many cement mines.
- Cat-3 – Closes habitation or public utility exists around 150m - Rajmahal OC, Dhanbad, etc.,

VI. Key Factors Impacting Environmental Issues Like Ground Vibrations, Air-Blast and Fly Rock

- Ground vibrations

Rock properties, Rock structure, Maximum charge per delay, Distance of habitation /public utility from blast site, Adequacy of delay time for each hole as per their location

- Air Blast –

Distance and direction of habitation /public utility from blast site, and weather conditions, Adequacy of delay time for each hole as per their location

- Fly rock –

Distance of habitation /public utility from blast site, Degree and duration of confinement of charges, Firing sequence.Environmental Constraints in mining operations increase, as the category of mines increases from Cat-1 to Cat- 3., that is to say, Cat 3 mines are most difficult to operate in terms of environmental issues. The charge per delay goes down drastically in Cat -3 mines. The blasting operations become less efficient due to charge per delay restrictions and limitation of charges and thereby achieving desired fragmentation size is becoming difficult by using less flexible and inaccurate delay systems in use today.

VII. Today's Blasting Scenario

A blasting engineer in a mine today, must conduct blast using fixed interval, less accurate delay systems, where

- rocks of different rock strength's, rock structure, seismic velocity
- burden and spacing vary bench to bench
- bench height varies from bench to bench
- blast size varies from extremely small to very large.
- blast block length / blast block width ratios vary 1 to 4.
- excessive burdens exist in front rows (crest as well as toe).
- excessive spacing exists at few holes

VIII. Electronic Detonators – How They Help in Improving Safety and Mitigating Risks

The electronic delay detonators are designed to have Flexible and Field programmable delay times ranging from

1-10000 milliseconds. Blasting engineer has a choice in picking right delay times / choicest delay times on the field.

TABLE I : MINING COSTS REDUCTION – ELECTRONIC DETONATORS – ` COST SAVINGS – BY INCREASING BLAST SIZE

Rock	Annual Production	Approx work stoppage cost/ hr (Lakh)	ABS - conventional system	ABS -electronic detonators	Likely Savings (₹)
Hard Iron ore	15MT Capital ₹1200 Lakhs	0.5	40000 T	100000 T	60% time costs- 112 Lakhs
Coal mine	15MT, 60 MOB Capital	2.0	100000 cum	250000 Cum	60 % time costs 750 Lakhs

They are designed to be accurate to the extent of 0.02 % of assigned delay time, over the range of delay from 1-10000 milliseconds. Blasting engineer can now be confident that, each hole goes at the assigned delay time, as per the guaranteed accuracy. They are designed to have consistency in accuracy in each batch, each supply, each consignment. Blasting engineer now has less worry on blasting particularly when blasting closer to public utilities / structure. They are designed to have accuracy even when the product supplied is used after a long period. Blasting engineer now need not worry about increase of delay scatter with time. The benefits of the electronic detonator system are

1. Good control on blasting operations, - improvement in safety and segregation blasts are more possible
2. Improvement in fragmentation as we can assign right delay time – improvement in productivity
3. Improvement in final line of control of each blast – improvement in safety as back break is under control, Less boulder generation from overhangs
4. Improvement on Blast control - improved control on GV, Air blast as planned maximum charge per delay can be implemented, using multiple decks, and elimination of overlap of delays
5. Improvement in blast size is possible – reduction in mining costs-the idle time cost of machinery falls drastically as blast size increases.
6. Improvement in HEMM productivity - Fragmentation increase, Boulder formation reduction, increase in operating hours for HEMM due to reduced time.

IX. OUR EXPERIENCE'S IN BLASTING WITH ELECTRONIC DETONATORS S IN INDIAN MINES OVER LAST FEW YEARS

We started manufacturing electronic detonators indigenously way back in 2004. Over the years, we conducted many blasts in coal mines, limestone mines and metal mines using electronic detonators. We demonstrated to the mines, how the electronic detonators help them in improving safety and mitigate costs and risks associated due to work stoppages, disruptions, increased downtime of machinery etc., We wish to share a few observations

a) Blasting in Dragline benches – Singrauli Area

The Jayanth and Dudichua mines located in Singrauli area of NCL have higher stripping ratios, and use high capacity HEMM. The operating bench heights for Draglines range from 30-45 mts and for front end shovels 15-20mts. The drills in use are 259mm and 317mm diameter, where 65-70kg/m and 85-90 Kgs/m of charges are in use. Detonating cord with Cord-relay system is in use for initiating charges. The outer boundaries of mines are at 700-750meters from habitation. In the year F-2016, we understand that, villagers started raising concerns about ground vibrations and noise levels and their apprehensions on safety, the management of NCL mines decided to conduct few blasts using Electronic detonator system, to mitigate the concerns raised by villagers. NCL management, also intended to study simultaneously, whether break down-time of dragline operation comes down, using electronic detonators. The blast results using electronic detonators indicated that that the concerns of villagers and break down time for dragline operation reduced.

b) Blasting long patches in Iron ore mines – Barbil Area

The Iron ore mines of TATA group located in Barbil area, wants to study whether the blast size can be increased, without losing control on ground vibrations, noise and fragmentation needs, by using electronic detonators. Each mine of Tata Group, located in Barbil area, excavate around 10-15 Million tons ROM each year operating on 10 meter benches, using 165mm drills, and 4- 6 cum capacity front end excavators. The blast size ranges from 80m to120m length. The average blast size is around 40000-50000 MT. We have conducted few blasts using electronic detonators by increasing blast block length up-to 320 meters. The blast results using electronic detonators indicated that blast block length increase helps in reducing number of blast events, reduce mining costs as the downtime of machinery due to blast events reduces, and the set blast objective of getting good break fragmentation, minimum back break, control of ground vibrations and noise can be achieved.

c) Blasting in extremely challenging conditions in hard rock mines of HZL –RA mines

HZL –RA mine is considered as one of the largest capacity hard rock mines in the world, excavating ROM of 80-90 Million per annum. The mine has many unique features. There are many varieties of rocks like amphibolites, garnet-biotite-sillimanite-schists, pegmatites, etc., The mine lease area is limited in terms of PIT WIDTH and mine has reached depth's up-to 230meters. The operating bench height of mine is 10m and the drills used are 165 mm diameter. The mines use 42 Cum shovels along with 240 MT dumpers for faster rock removal without overcrowding mine with machinery. To extract such large quantities per annum, the mine conduct 's large to very large length blasts, controlling roll over of fragments to bottom benches. The number of benches being large, say + 21, maintaining bench slope stability, is an important issue.

The mine started using electronic detonators extensively few years back, as a tool to maintain bench slope stability, to maintain desired fragment size, to control fly rock related accidents, and to reduce back break even while conducting large length blasts. We have conducted many blasts using electronic detonators in the mines and the blast results indicate, the set objectives of the mine like maintaining bench slope stability, control of throw, back break, fly rock, are fully met even when blast block length is larger.

d) Blasting under controlled conditions where the public /private structures are located at 60-250 meters

In India, many OC mines belonging to public sector and private sector group are being operated very close to habitation due to land lease issues. The concerns/ issues at these locations are, high cost and risk associated with stoppage of mines for few hours to few days, for the reasons of noise, ground vibrations, fly-rock etc., At many mines, work stoppages / disruption were more frequent. To mitigate these issues, the management of the mines started using electronic detonators few years back and found from blast results, using electronic detonators that the concerned issues were largely mitigated and mines could produce the mineral with less interruptions /disruptions.

e) *Blasting on wider drill patterns*

Customer in general would like to explore whether the additional cost incurred on electronic detonator system can be recovered without increase of blast size. We, as a manufacturer and supplier of system, demonstrated at few locations like Limestone mine located at Kotputli, two Iron ore mines of a private company located at Barbil, that the customer can operate at wider patterns, using electronic detonator system without increasing the charge quantity. The blast results, using electronic detonators on wider patterns, indicated, that there is a scope to increasing drill patterns, without foregoing benefits of fragmentation like excavator /crusher productivity

X. Conclusion

Electronic detonators play an important roll to improve mine safety and to mitigate costs and risks associated due to work stoppages/ disruptions. They are an enabling tool for a mining engineer in safe and faster excavation. They are also an enabling factor in maintaining bench slopes, and conducting blasts closer to habitation. In the years to come, the technology, electronic detonator is going to become a tool for reducing mining costs without foregoing anything on safety.

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References

[1] SCCL and HZL Technical Reports (unpublished).