Enhancement of Drilling & Blasting efficiency in Opencast and Underground Mines

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Use of Modern precision Drilling, Electronic Delay Detonator system and other sophisticated Equipments with New-generation Emulsion Explosives are the need-of-the hour.

Author - Partha Das Sharma (B.Tech-Hons. In Mining Engg.)
E.mail- **sharmapd1@gmail.com**, **sharmapd1@rediffmail.com**)

Introduction: Computerized drilling and electronic detonators add precision at the mines to lower downstream costs. Gaining a competitive edge in a mature and basic industry like underground and opencast mines / quarries, it has taken a major leap forward in enhancement of Techno-Economics advantages in working of mines.

Drilling and Blasting is the most important activities in working of any mines. In particular, electronics are bringing a level of unprecedented precision to the process of breaking rock in the mines. Computerized drills, **Measure-While-Drilling (MWD)** systems, and electronic detonators, are gaining wider acceptance in quarries, opencast and underground mines.

Cost centers such as drilling, blasting, excavation, hauling and crushing are seen as interrelated variables in the total cost equation. As the first step in this interrelated process, improved results from drilling and blasting; even if it costs more; can significantly improve costs and productivity of downstream cost centers such as excavating, hauling, and crushing. In order for the advances in blasting technology to effectively reduce the mining industry's cost equation, smart equipment and other innovative measurement technologies will need to be developed or advanced so that information can flow back into the process for continuous improvement.

Moreover, as development of Emulsion Explosives has effectively substituted need of Nitroglycerine based and Slurry based explosives, introduction of sophisticated measuring instruments with improved software etc. have resulted in achieving better Techno-Economics in mining operation.

1) Precise Digital Drilling:

Computerized drills and MWD systems are two technologies that can provide feedback on important aspects of the drilling function:

- Correct location and depth of blast holes.
- Accurate recording of 'as-drilled' conditions.

Computerized drilling systems provide the capability to automate the drilling process, which can increase machine utilization, improvement in drilling accuracy, which helps optimize blasting and improve safety.

In a **CAN-bus system (Controller Area Network)** of drilling, which comprising a number of small on-board computers linked by a single cable, all hydraulics have been removed from the cab and a color monitor replaces traditional dials and gauges.

A **Rig Control System (RCS)** senses variations in rock conditions and adjusts drilling functions to optimize drill penetration and accuracy and to minimize consumption of drill tools. While drilling, the system logs deviations and other parameters for later analysis, which can reveal geologic or hole conditions that can impact explosives loading or other blasting plans. MWD parameters include penetration rate, percussion pressure, feeder pressure, damper pressure, rotation speed, rotation pressure, and flush air pressure.

Use of a **Global positioning System (GPS)** for accurately positioning the rig to drill holes according to the blast design without surveying or staking allows ease and efficient operation. Sometime, blast hole drill monitoring and navigation system that allows operators to get within approximately 8 in. of the designed hole location without staking. A color monitor display shows the operator where every hole should be drilled as well as the location of previously drilled holes. As the drill moves around the drill pattern, the map moves on the operator's display to allow quick navigation between holes and a visual lock ring function indicates when the drill is positioned within tolerance of the design location of a hole. Map data is transferred to and from the drill via spread spectrum radio.

In some drill system, GPS system uses **Real Time Kinetic (RTK)** positioning technology, which is 100 times more accurate than Differential GPS and only requires a short initialization period on power up to achieve centimeter-level accuracy. The system also indicates the elevation above sea level of the drill bit as the hole is drilled. Consequently, the target bottom of each hole can be specified as an elevation, rather than a depth, to reduce under- and over-drilling, eliminate hard-digging toes, and create level benches.

Necessary software is loaded to perform above precision activities such as providing feedback to the operator on drilling productivity and performance, analyze drill variables and determine hole geology while drilling etc. Together, these parameters provide real-time geological information that can improve explosives use and produce better fragmentation. Thereby, the rig utilization overall efficiency can be increased nearly by 10 to 15 percent by implementing these automated functions.

2) Precise Delay Detonation system:

Just as accurate hole location and drilling can improve fragmentation and decrease fly-rock and vibration (all affected by actual hole burden and explosives loading), so too can the timing of detonation of each hole. Elaborate blast designs with multiple delays between holes and rows are only as effective as the precision of the millisecond (ms) delays used. Electronic detonators with precise delays have quickly moved from experimental and developmental stages to commercial use in mines. Refer Note on Electronic Detonators below.

Accurate and flexible timing, however, allows blasters to make small hole-to-hole and row-to-row changes to account for drilling inaccuracies. Adjusting the blast design to actual conditions can improve safety and fragmentation, which can cut costs by optimizing the loading and hauling cycle, increasing crusher throughput, and reducing the amount of oversize handling and secondary breaking. In addition, precise and variable delay timing manipulations have enhanced high-wall stability and bench crest preservation, resulting in safer mines operations and also for reduction of blast induced ground vibration. These improvements allow for more accurate placement of boreholes for succeeding blasts. Optimization of the blast design to take greater advantage of the electronic detonators' precision was expected to expand the blast pattern and reduce the explosive consumption without negatively affecting production.

Electronic detonators generally are programmable in 1-ms increments and have delay accuracy (scattering) as small as ±0.5 ms. Many blasting engineers reported the following results:

- 32-percent decrease in the mean size of rock in the post-blast muck pile.

- 37-percent increase in 8-in.-minus rock.
- 25-percent reduction in digging time to excavate the muck pile.
- 6- to 10-percent savings in primary crushing costs, measured by power consumption.

NOTE ON ELECTRONIC DETONATORS

The mining and explosive industries rapidly adopting new technology, in all forms, in order to improve overall performance, efficiency and cost effectiveness. One such technology that is being developed to improve techno economic related matters in usage of explosive and blasting efficiency.

There are several types of electronic systems being tested and used in the mining industry, all of which utilize some type of stored energy device to provide energy for their timing and firing circuits. All Electronic Detonators has a system to store electrical energy inside the detonator as a means of providing delay timing and initiation energy.

All other existing conventional detonator technologies including shock tube, electric or safety fuse etc. utilizes pyrotechnic energy as a means of delay and initiation. Although construction of electronic detonator may not appear to be significantly different, there is a very basic design difference between an electronic detonator with other two shock tube and electric detonators.

One of the basic differences in electronic delay with pyrotechnic system of delay lies in the location of Igniter. In electronic detonator the Igniter is located below the delay (timing) module, whereas both shock tube and electric detonator utilize the Igniter ahead of delay element (shock tube function as Igniter in the shock tube device).

Other basic difference in design of electronic detonator is the use of some type of stored electrical energy device, typically capacitor, is used in the delay module. The construction and design of electronic detonator varies from manufacturer to manufacturer.

As discussed the electronic detonator utilizes standard shock tube lead as the input signal, which is transformed into electrical pulse through the use of principal component : A small explosive charge (booster) coupled to a highly efficient piazo ceramic element (generator) and (electrical energy storage cell (capacitor). Upon receipt of a thermal signal from shock tube the small explosive charge in the booster detonator fires. This activates the piezo ceramic device, which in turn causes current to flow through the steering diode to charge storage capacitor. A voltage regulator provides a substantially constant voltage source to oscillator to control the frequency. A "power on reset" circuit preloads the counter upon the initial application of the input voltage. Once the voltage on the storage capacitor has increased beyond a threshold setting the counter begin decrementing upon each input pulse from oscillator. As the counter digitally decrement past zero, the output to the firing switch activate and all remaining energy in the storage capacitor flows to the Igniter. The end result is an electronic delay detonator. Electronic Detonator system can be grouped into two basic categories: (1) Factory programmed system. (2) Field programmed system.

Factory programmed system generally have a close resemblance to the conventional system of standard pyrotechnic electric/shock tube detonators. Factory programmed system utilizes fixed delay period for the blast design. Holes are generally loaded and hooked up in the same manner as with standard electric and shock tube system. Field programmed system utilizes electronic technology to programmed delay timings "on the site". There is no fixed delay times associated with these detonators. These systems rely on direct communication with the detonators for proper delay time as per design of blast, either prior to loading, after loading or just prior to firing. In-fact the system utilize some type of electronic memory which allows them to be programmed at any time until the fire command is given.

A few companies abroad have come up with electronic detonator system with the capability of **remote programming and remote initiation**. The blasting sequence can be sent and the blast initiated by an encrypted radio frequency protocol. This eliminates the use of lead-in cable and increases the safety distance from the blast to the firing point, up to several kilometers, if needed.

3) Blast design software now-a-days have become foundation in drilling and blasting job in big mines in developed countries. Using the Blast design software a blasting engineer can create the timing design in the office, simulate the blast on a PC, then optimize the design before providing the blast plan to field personnel.

4) Other Modern Technology & Equipment used:

i) **Modern surveying equipment** and its Computer Software provide a wealth of valuable information on a blast and post-blast scenario. These include overburden – coal ratio, optimum front hole location, custom loading information for front row hole burden, pre-blast mapping, post-blast mapping & determination of cast / throw, volumetric calculation for swell factor and cast percentage for basis of evaluation of economic advantages.

ii) **High Speed Photography** recording is very efficient and extremely useful instrument for analyzing of blasts. Any hindrance in free movement of projectiles or air collision of fragments can be detected and accordingly delay sequence timing can be adjusted. Now a days, high speed photography to the tune of more than 500 frames per second is in vogue, which is very useful for the purpose.

iii) **Velocity of Detonation Recorder** is another useful instrument which can be used to determine explosive performance in the hole.

iv) **Seismograph or Ground vibration recorder** is essential in documenting the un-wanted side effects of blasting such as Ground vibration and Air blast.

5) EMULSION EXPLOSIVES:

Nitroglycerine based explosives have been the workhorse of hard rock blasting in mines for more than 100 years. ANFO and slurries, though easier to store, handle and use fall far behind in performance as compared to Nitroglycerine based explosives. Years of research have led to development of emulsion explosives.

Emulsion explosives are the intimate and homogenous mixer of oxidiser and fuels. It consists of micro droplets of Super – Saturated oxidiser solution with oil matrix. These are in the form of water – in – oil emulsion. The internal phase is composed of solution of oxidiser salts e.g. Ammonium Nitrate etc. dispersed as microscopically fine droplets, which are surrounded by a continuous fuel phase. The emulsion thus formed is stabilized against liquid separation by an emulsifying agent.

A bulking/gassing agent – for density control, is then dispersed thorough out the basic emulsion matrix. The gassing agent can either be ultra fine air bubbles or artificial bubbles from glass, resin or plastic. The bulking agents determine and control the sensitivity of emulsion products – whether emulsion is cap sensitive or booster sensitive.

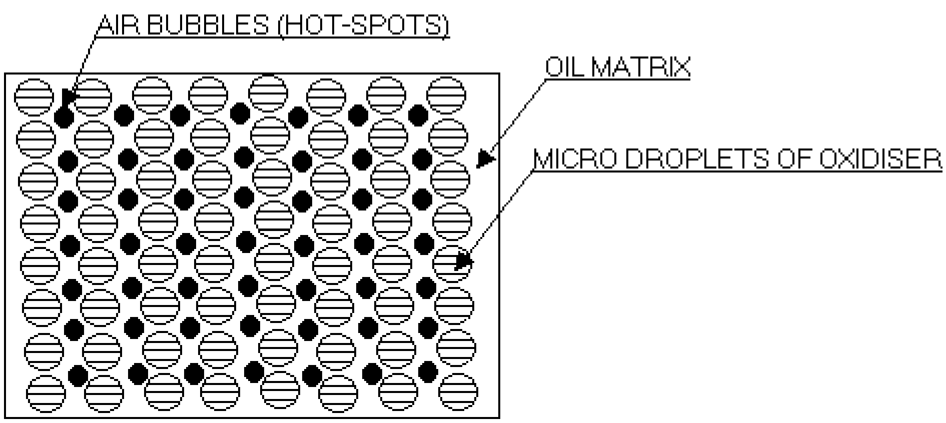
Since its micro cell is coated with an oily exterior, the emulsion has excellent water resistance property.

The output energy of emulsion is very near to the calculated energy.

Viscosity of emulsion can be varied by changing type of fuel oil used. Thus emulsion explosive can be made from putty type consistency to pump able type consistency. Therefore emulsion explosives can be made in cartridge form or can be used as bulk explosive in opencast as well as in underground mines.

The ultra fine air bubbles or artificial air bubbles used as gassing agent acts as sensitiser. When initiating shock wave applies to emulsion explosives the ultra fine air bubbles gets heated first and act as 'Hot-spots' in emulsion having very high temperature (about 1500 -1800 °C). At this high temperature the explosive reaction takes place.

The resulting emulsion can serve as detonable matrices to carry solid fuel such as Aluminium powder, prilled AN etc.,



EMULSION EXPLOSIVES

Properties of Emulsion Explosives:

1. Much better water resistant than water gel slurry or ANFO, as oil phase is at outside and water phase is enveloped within oil phase (Water – in – oil emulsion).

2. Emulsion explosives are much safer to handle, use and store as it is relatively insensitivity to detonation by friction, impact or fire.

3. High VOD can be obtained. VOD depend upon the oxidixer droplet size (0.2 to 10 micron)

4. Critical diameter of emulsion explosives again depend upon droplet size and sensitiser used. Now a days emulsion explosives having 25mm dia cartridge are also being used for underground blasting very effectively

5. Higher energy can be obtained by emulsion explosives than water gel slurries or ANFO because of the intimate mixture between oxidizer and fuel.

Conclusion: Thus, implementing modern and precise technology for operation of mines, improvement in efficiency and Techno-Economics level can be achieved in positive direction.

For obtaining high level of production with minimum cost and in order to increase in productivity, one has to judiciously think about adoption of modern and precise technology.

References:

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<u>Author's Bio-data</u>: Author is, at present, in charge of Marketing & Technical Services in SOLAR GROUP OF EXPLOSIVES INDUSTRIES, NAGPUR, engaged in manufacturing and supply of almost all range of Cartridge Explosives, Bulk explosives & detonators. This company, within a very short span of time, has emerged as one of the leading manufacturer, supplier and exporter of Explosives & Detonators in India. Visited number of African countries in order to organize seminars, Training and offering Technical Services to the various overseas customers.

Author has presented number of technical papers in various seminars and Mining Journals. Topics he dealt with in his various technical papers include Blast overburden Side casting, Complexity of Blast induced Ground Vibration in various related situations and its control, Tunnel blasting, Shock Tube and Non-Electric Detonators, Blasting in Metalliferous underground mine workings, Eco-friendly Non-primary Explosives Detonators (NPED) etc.

Author is Graduate (B.Tech – Hons.) in Mining Engineering from IIT, Kharagpur (1979) and was associated with number of mining and explosives organizations, namely MOIL, BALCO, Century Cement, Anil Chemicals, VBC Industries, Mah. Explosives etc., before joining the present organization a couple years back. Author can be contacted at E-mail: sharmapd1@rediffmail.com