Electronic delay detonators-benefits and growth prospects in India

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***Abstract*—Since the invention of Gunpowder in 1860 by Alfred Nobel mining industry was in need of initiating devices which helps in increasing blast size, improve safety during charging & blasting operation, as well as explosive performance. From Plain detonators & Safety fuse system to Shock-tube initiation system, commercial basting has made helped the above cause, however each system has some limitation in terms of accuracy of delay, safety requirement as well as complexity required in terms blast requirement of modern mining industry. Electronic Delay Detonators have came long way since their invention in late 90s. They have helped Blasting Engineers in solving modern mining requirement of Large blast with minimum Vibration, Better control on fragmentation, Blasting multi layer rock together, controlling throw & back break etc. Electronic Delay Detonators have been introduced in the Indian market in last 7-8 years mainly for Vibration controls. With increase knowledge Indian mining industry is now ready to embrace the other technological benefits of Electronic detonators. The papers make an attempt to highlight the benefits associated with use of Electronic detonators & future growth prospects of the same in Indian Mining & Construction industry.**

Keywords—Electronic detonator; blasting; ground vibration.

I. INTRODUCTION

Electronic Detonator Technology is an Electronic Detonator (EDD), delay is achieved electronically; a computer chip is used to control delay timing "*Fig.1*". An integrated circuit chip and a capacitor internal to each detonator control the initiation time. EDD technology which has evolved over time can be categorised as below.

A. Daisy Chain Communication -4 wire system

The system is having Dual voltage system. Information of delay is stored inside the detonator. The detonators can be Pre-programmed, Semi programmed or Fully programmed.

B. Bus wire communication (two wire system)

Two wire EDD are fully programmable. There can many variant in which delay timing can be assigned to the detonator or position in the shot can be assigned to the detonator. In the former case information can be stored inside the detonator or inside the equipment controlling the delay while in the later case it is stored inside the control equipment. Most of the system adopts dual voltage system for better safety "*Fig 2*".

C. Wireless EDD

Wireless EDD are also available in some countries. This doesn't need any bus /harness wire for connecting holes. The EDD along with boosters are lowered inside the hole and EDDs are programmed wire lessely.

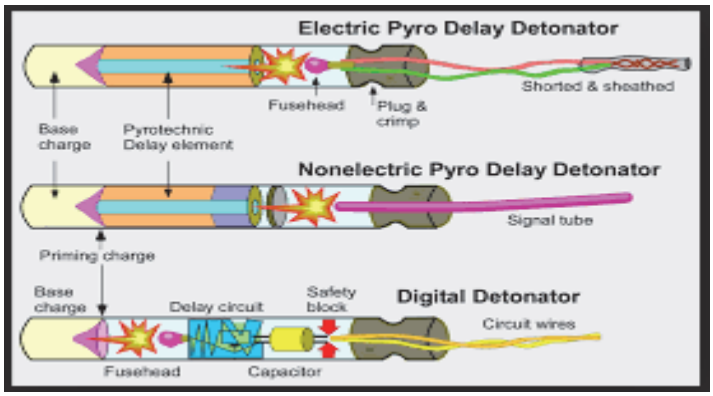

Fig.1. Shows the construction detail of Electric delay detonator, Shocktube detonator & wired Electronic detonator

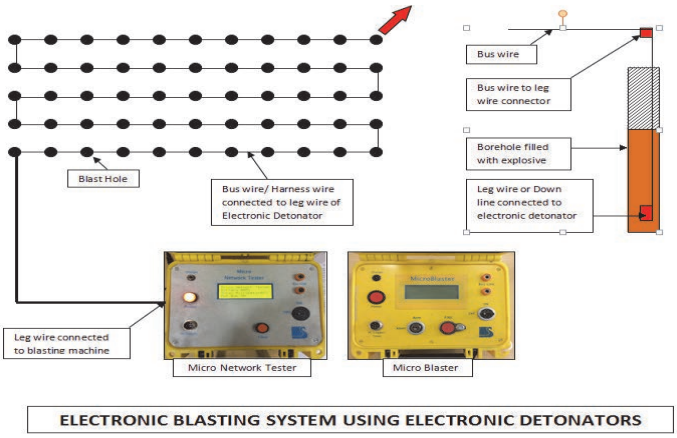

Fig.2. Shows the connection of EDD with bus wire & Blasting machine

II. ADVANTAGE OF ELECTRONIC DETONATOR

An EDD have number of advantages, e.g. higher precision, improved blasting result owing to a wide range of delays, reduction of air blast/ground vibration, and safe use in extraneous electric environments, and the possibility of limiting the amount of detonators per shot. It has some

disadvantages too, e.g. higher cost per detonator and the need for intensive training for users.

EDD have been introduced in Indian mining almost 10 years back. The product was mainly used for controlling environmental issues viz Vibration & Air blast. With rapid urbanisation, increase in mechanisation & production requirement, controlling vibration & Air blast becoming most challenging aspect of mining in India. With tighter norms of vibration limits as posed by statutory bodies, EDDs are helping mining companies to carry out blasting activity in more environmental friendly way. Indian mining companies are making attempts made to harness the other benefits associated with use of EDDs.

Benefits by use of EDDs are summarized as below

1. Environmental Control
2. Better Fragmentation
3. Better control over Muck pile shape
4. Wall & Back-break control
5. Increase in blast size
6. Opportunity to increase pattern
7. Blasting multilayer rock formation etc

Some of the above benefits are described below

A. Environmental Control

With EDD coupled with vibration prediction tool, vibration can be predicted at various points, particularly sensitive ones. Due to accuracy of the timing of EDD, the explosive energy is released at the exact time it was set to; there are no unplanned spikes in energy (and therefore vibrations).

The study by [7] examines the structural response to blast-induced ground vibration. He underlines the importance, from an environmental point of view, of minimizing vibrations induced in urban dwellings by blasting. The maximum response of a house to blast-induced ground vibration occurs whenever the frequency of the ground vibration matches the natural resonant frequency of the house: if there is little or no energy at the resonant frequency of the structure, the structural response to the vibration will be negligible.

By choosing delay times (Δt) that create “destructive interference” at frequencies that are favored by local geology, the vibration that excites structural elements could be reduced "*Fig. 3"*. In this method, accurate delay times are crucial to effective vibration control. Electronic detonators have less than 1 ms scatter. In this light, researchers have started to find both limitations and new potential in this new technique of controlling blast vibration. The computer analysis determines the application of delay timing between holes, between rows and between decks which would produce the most favorable blast-induced vibrations for buildings and urban dwellings. The study conducted by Decon C & Duniam P and Bartley Da & Trousselle R has shown reduction in PPV by use EDD in comparison with Pyrotechnic delays (PD). The data were compared of the above studies were are pasted *"Fig. 4"*.

Few studies have evaluated the increase in frequency by use of EDD. Summary of some these studies are tabulated *"Table.1"*.The higher frequency is obtained by EDD are very helpful aspect in managing vibration limits. As the structures

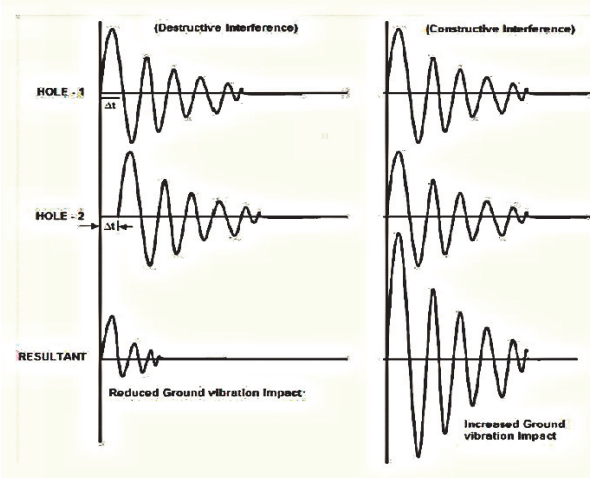

Fig.3. Destructive and constructive interference

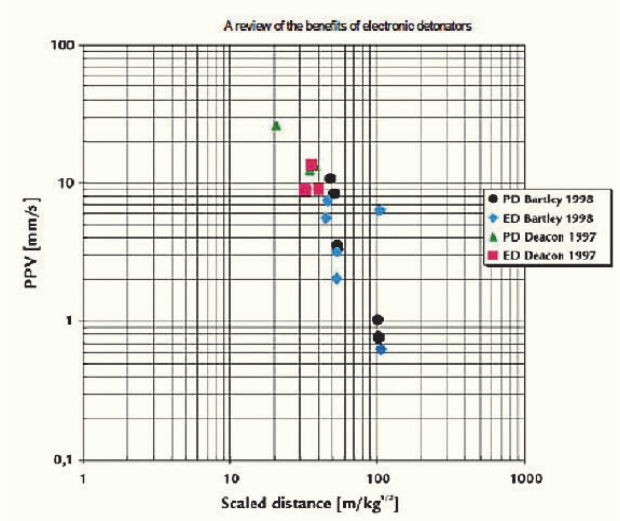

Fig. 4. The PPV data from deacon st al.(1997) and bartley et al.(1998) have been processed to obtain comparison between ED and PD

are more prone to damage in low frequency range as compared to higher frequency range

TABLE 1 COMPARISON BETWEEN DIFFERENT FREQUENCY VALUES USING ED AND PD FIRINGS SEPARATELY.

Authors	ED	PD	%
Bartley D.A., Trousselle R. 1998	26 - 64 Hz	20 - 47 Hz	30 - 36 %
Carter R.A., 2002	26 - 39 Hz	8 - 20 Hz	> 95 %
Bartley D.A.,Winfiled B., McClure R., Trousselle R., 2000	13 - 63 Hz	19 - 55 Hz	- 31 - 15 %
McFerron W., Moodley P., 2004	30 - 71 Hz	26 - 57 Hz	15 - 25 %

.Some researchers have also reported reduction in airblast levels also in comparison to PD. [4] has reported reduction of Air blast by 15% from 127 dB to 108dB. McFerren has observed reduction of Air blast by 3%.

B. *Better Fragmentation*

No formal information is available on primary reason by various customers for use of EDD over PD or other systems. However improvement in Fragmentation seems to be second biggest reason for increase in use of EDD. Better fragmentation also impacts the downstream operations of mining.

Grobler (2003) refers to the results obtained in surface mining, particularly on the log linear plot of muck pile; EDD produced a reduction in the upper size and the fines. In contrast, the grain size distributions related to EDD, evaluated by [9] and Havermann are systematically higher compared to PD. The study by [3], of the post blast muck pile excavation indicated a 25% reduction in dig time using EDD. Moreover, the crushing operations show a reduction of electric power consumption (kWh/t) of about 6 -10 % if EDDs are employed. When EDDs are employed, thanks to the improvement of the fragmentation, the block size distribution is upgraded (in comparison with PD) as follows:

maximum block size: reduction of 24 %.
mean size: reduction of 25 %.
minimum size: reduction of 10 %.

Piyush Rai has reported reduction of mean fragment size from 0.55-0.59 m (with PD) to 0.43-0.45 m by use of Electronic detonator in hard rock formation.

C. *Better control over Muck pile shape*

Muck pile requirement for Dragline , Shovels & Wheel loaders are different. With EDD's advanced timing, it's possible to speed up and slow down certain parts of the shot to change the muckpile profile. A basic rule is that a hole that detonates a long time after the hole next to it will tend to move into the gap where the last hole was. It's possible to change the height of the pile and where the pile sits by changing the timing between the holes.

D. *Other Benefits*

The overarching goal for drill and blast is to use the raw energy from the bulk product to do the most useful work on the rock. In most mines, the bulk product cost is more than all other drill and blast costs combined. EDD when used to their potential will achieve more with the rock using the same energy. Depending on the mine's situation, this can deliver increased productivity or assist to reduce costs by blasting the rock better so it digs faster and the mine produces more for the same cost. With accurate timings of EDD it is possible to reduce back break & control wall damage.

Idling of mining machinery during the time of blast as well as wear & tear of mining equipment due to shifting away the blast face can be reduced with increasing the size of blast without increasing the vibration limits. Some of the Indian mine has reported increase in blast size by 40-50% in critical area.

Also it is possible with EDD to blast multiple coal seam or seam having steep gradient along with intermittent burden, in metal mines ore & waste can be blasted together, with very low dilution.

III. EDD INDIAN SCENARIO

EDD in India are provided by three manufacturer & are available in two varieties i.e. Factory Programmable EDD & On-field Programmable EDD. The factory programmable EDD have fixed delay timings as programmed during the manufacturing process. On-field EDD can be programmed at site depending the blasting requirement of the site.

Economic Explosives Ltd (EEL) which is part of Solar group is leading supplier of EDD in India. EEL's EDD developed & manufactured by adhering to the core principle of Inherent safety. EEL's Electronic detonators blasting system consists of following elements

- Programmable Electronic Detonator - MICRODET-1
- Micro Logger- For assigning delay timing to Microdet-1
- Bus wire - For connecting all the holes in the shot
- Micro Tester - For Checking the circuit once the holes are connected
- Micro Blaster - Device for Firing the holes charged with Microdet-1

A. *Microdet-1*

Microdet -1 EDD can be programmed at site & contains Microprocessor Chip with Digital Timing Circuit. Important design features of the product are listed below.

- Can provides delays up to 8000 ms at a interval of 1 ms
- Each detonator has a unique detonator ID number
- Chip provides the desired delay timing to the Base charge.
- Chip & Capacitor has the capacity to safely store, release energy and allow firing sequence.

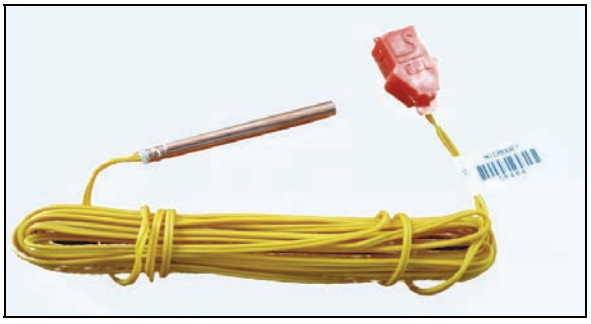

Fig. 5. Electronic detonator with leg wires

- It has also got all safety features to prevent firing due to stray current, Electromagnetic waves etc
- *Lead wire:* Lead wire consist of Twin copper/ copper coated still wire with PVC coating connects Detonator to Connector
- *Connector:* The connector is a hinged plastic device & connects the Individual detonator to the main bus line.

- *Lead Wire Spool:* The lead wire is coiled on to a plastic spool which also can house the detonator in the centre shaft space

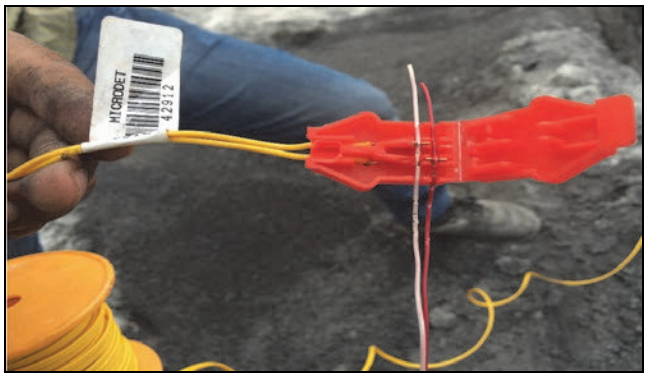

Fig .6. Connector connecting bus wire & Leg wire of Microdet 1

B. *Micro Logger - For assigning delay timing to Microdet-1*

The Micro logger is used to set the delay time. It has the required capability to store information like hole number, detonator ID, delay timings. While logging one end of the logging cable is attached to logger & the other end to Microdet-1 thru connector.

All the logging data from Micro Logger will be transferred to Micro tester for testing the circuit. Logging data also transferred to Micro Blaster before firing the shot.

Fig .7. Showing the micrologger.

C. *Micro Tester - For Checking the circuit once the holes are connected*

Micro Tester the capacity to test 500 nos. detonators. The data from logger is transferred from Micro Logger to Micro Tester through transfer cable. Micro network Tester communicates with all detonator units & shows connection connectivity to each of them. The delay timing of any Microdet1 units can be edited at this stage. It also check total resistance and also display "Short circuit" if any.

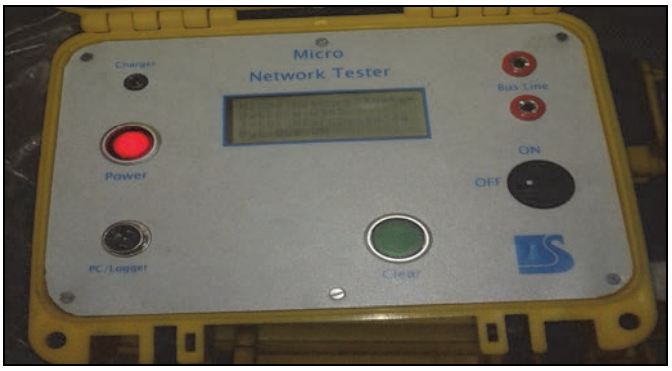

Fig. 8. Showing micro network tester

Fig. 9. Showing micro blaster

Fig.10. Large blast using Microdet 1 in Coal mine resulted in lower vibration.

It can detonate max 500 Microdet units. After checking the circuit thru Micro tester, before firing the data from Logger is tranferred to Blaster. When turned on and conected it again

D. *Micro Blaster -- Device for Firing the holes charged with Microdet-1*

again checks the integrity and continuity of the circuit. Once the Blaster ARM key is turned on all the detonators will be armed within 1 minutes and will be previously assigned delay timing. The firing at this stage can be Aborted by pressing “ABORT" button. All the detonators receive fire signal at the same time but fired according to the delay time given to them.

IV. FUTURE SCENARIO

With increase need of Coal production & growth of Mines in near habitant area & environmental concerns,

EDDs would play important role in helping Mining companies to address the above challenges. With increasing availability of Measurement tools for Fragmentation, wall control, vibration & Blast Modelling tools will also help growth EDD in India.

EDDs are also likely to help Construction blasting activities like Tunnelling in the cities & control blasting operation close to Sensitive structure. Development of Smart cities & rapid construction of Roads, increasing demand of aggregates would propel the demand for Control blasting with the help of EDDs.

With emphasis of GOI to increase the Coal production to One Billion Ton & growth of Mining in densely populated Eastern India Controlling Vibration & Air-blast will be key concern area for blasting.

EDDs consumption In India is likely to Grow to 1 Million No's by 2020 with major demand will come from Coal Sector. EDDs are also likely to be used extensively to Dragline blasts & other niche application.

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