Optimizing Blasting Efficiency through Advanced Automation Technologies at Khondbond Iron & Mn Mine, Tata Steel Ltd.

Saurabh Singh [a], Anup Kumar Roy [b]

[a]Senior Manager, [b]Safety Officer-Khondbond Iron & Mn. Mine, M/s Tata Steel Ltd.

1. Introduction:

Khondbond Iron & Mn Mine is a part of the Ore Mines & Quarries Division of Tata Steel with a lease area of 978.0 ha. The mine is situated near Joda in the Kenojhar District of Orissa. Mine is worked by the open-cast method on a series of benches in two. Deep hole blasting is being carried out at Khondbond Iron & Mn mine using Site Mix Emulsion (SME) Explosives along with the latest technologies, such as Advanced Vibration Monitoring (AVM) based blasting and electrotonic detonators being used with the NONEL system.

2. Process flow of Khondbond Iron Mine:

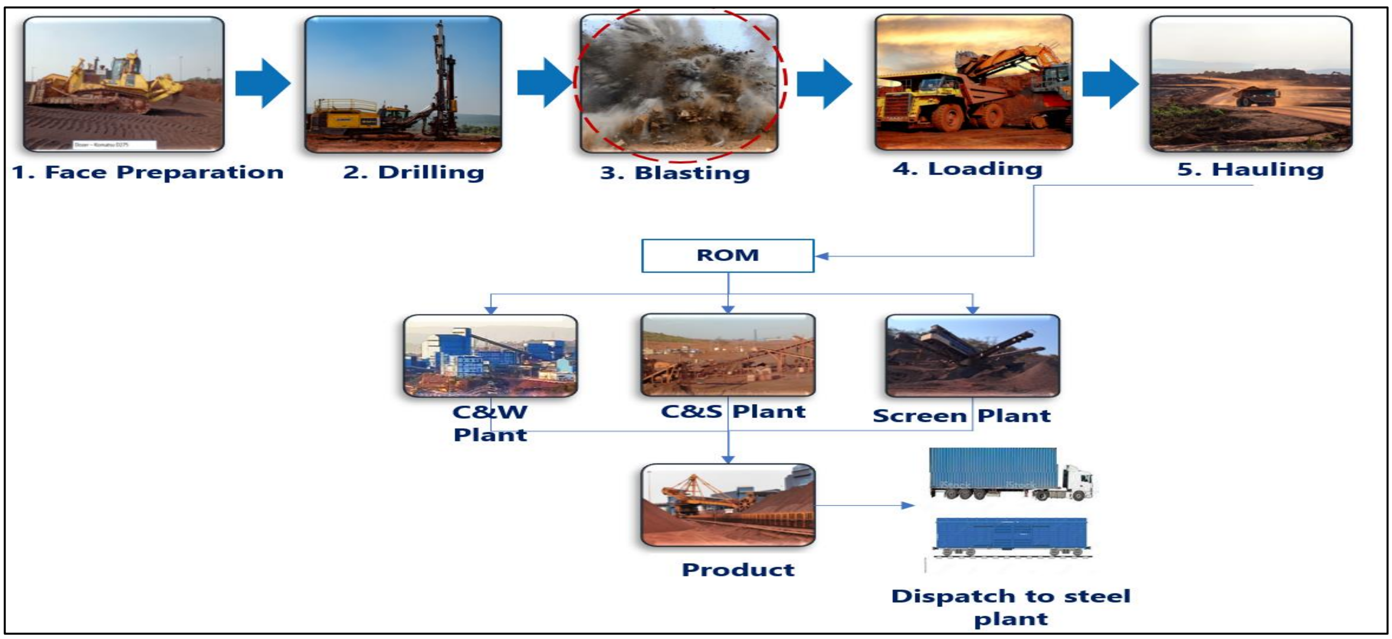


Fig 1: Process flow of Khondbond iron & Mn. Mine

3. Problem Statement:

One of the active mining pits of Khondbond Iron Mine, Pit-2, is situated at a very close proximity to critical infrastructure, such as High-Rate Thickener (approx. 100m away from blast patch), Sub Grade Dump and other structures along with the challenging geology of massive widely jointed hard ore strata, complicating the optimization between blast vibrations and rock fragmentation. Peak Particle Velocity (PPV) must be restricted to below 5 mm/s near these structures. Further, the adverse geology impairs fragmentation, leading to detention of Crushing & Wash Plant due to jamming of the boulder. With the existing blasting practices, the P_{80} value was in range of 800mm to 950mm, whereas the PPV was in the range of 4.2 mm/s to 6 mm/s with dominant frequency range varying between 3.125 Hz to 19.7 Hz.

PPV – Peak Particle Velocity; P_{80} - 80% passing size; Hz – Hertz; mm/s – milli meters per second; AVM – Advanced Vibration Modelling.

4. Approach to the Problem:

A. *Use of Advanced Technologies to Improve Blast Efficiency*

a. Use of Advanced Vibration Modelling (AVM) tools to predict PPV values prior to the blast at critical structures.
b. Regular Fragmentation Analysis to determine the P_{80} value for regular monitoring and improving the blast fragmentation.
c. Regular measurement of confined Velocity of Detonation (VOD) to test the strength of explosive.
d. Maintaining the digital blast reports to monitor and rectify any deviations from the plan.
e. Digital drill plans to facilitate accurate drilling operations.
f. Digital blast plan and simulating the blasthole delay timings to eliminate the chances of fly rock.

B. *Use of Electronic Detonators* – to provide flexibility and accuracy in delay timings.

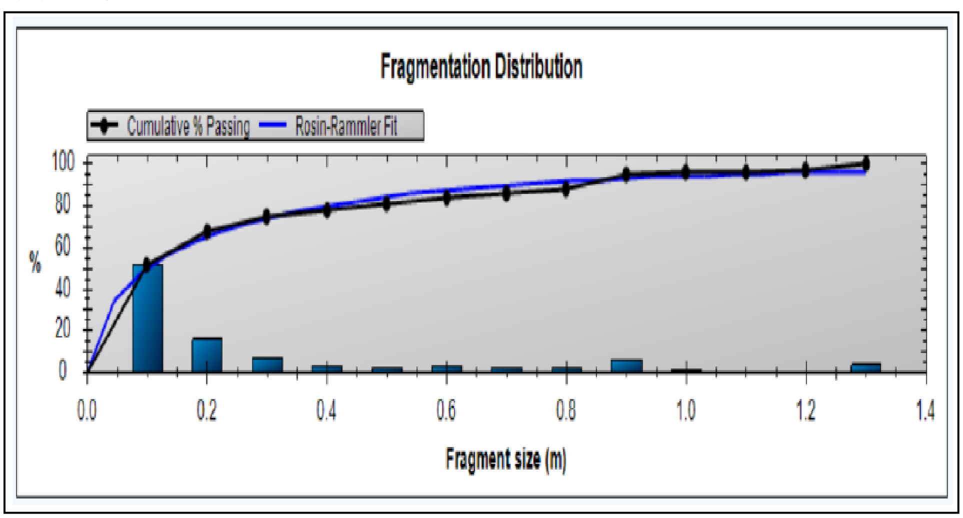
5. Parameters Selected for Field Experiment:

Field experiments are planned at Khondbond Iron Mine by varying the controllable parameters to optimize the blast induced vibration & fragmentation.

1. Maximum Charge Per Delay (MCPD) in Kg.
2. Delay Timings in Millisecond.
3. Burden in Metre.
4. Spacing in Metre.
5. Stemming Length in Metre.

6. Field Experiments:

6.1. Trial of drilling Pilot Hole (5m depth) in between the holes in bench of 10m height to eliminate the boulders generated from the drill hole collars (in stemming length the explosive is absent thus boulders are generated from the top column of the blasthole), resulting in improved fragmentation with P_{80} value of 407 mm.



Graph 1: Fragmentation results of Pilot Hole experiment

PPV – Peak Particle Velocity; MCPD – Maximum Charge per Delay

6.2. Varying the MCPD and delay timings:

Five experiments were performed by varying Maximum Charge per Delay (MCPD) and inter hole & inter row delay timings to observe the effects of MCPD and delay timings on Blast induced ground vibrations (PPV values) and blast fragmentation (P_{80} value).

Design of Experiment-1(DOE-1)

- ✓ The inter-deck delay is 4ms and inter-hole delay is 20ms and MCPD is 120 kg.
- ✓ The POI distance to blast face is about 235 m and vibration got 5.2 mm/s.
- ✓ 80% of passing fragments size is 557 mm.

Design of Experiment-2 (DOE-2)

- ✓ The inter-deck delay is 2ms and inter-hole delay is 8ms and MCPD is 90 kg.
- ✓ The POI distance to blast face is about 240 m and vibration got 4.8 mm/s.
- ✓ 80% of passing fragments size is 460 mm.

Design of Experiment-3 (DOE-3)

- ✓ The inter-deck delay is 3ms and inter-hole delay is 12ms and MCPD is 75 kg.
- ✓ The POI distance to blast face is about 227 m and vibration got 3.3 mm/s.
- ✓ 80% of passing fragments size is 466 mm.

Design of Experiment-4 (DOE-4)

- ✓ The inter-deck delay is 4ms and inter-hole delay is 20ms and MCPD is 100 kg.
- ✓ The POI distance to blast face is about 210 m and vibration got 4.9 mm/s.
- ✓ 80% of passing fragments size is 491 mm.

Design of Experiment-5 (DOE-5)

- ✓ The inter-deck delay is 4ms and inter-hole delay is 16ms and MCPD is 80 kg.
- ✓ The POI distance to blast face is about 227 m and vibration got 3.2 mm/s.
- ✓ 80% of passing fragments size is 483 mm.

Parameters	DOE-1	DOE-2	DOE-3	DOE-4	DOE-5
Location – Pit-2	680mRL				
No. of holes	37	51	37	49	46
Burden (Metre)	3.2	2.8	2.8	2.8	3
Spacing (Metre)	3.2	3.2	3.2	3.2	3.2
Hole depth (Metre)	11	11.5	11	11.5	11
Stemming (Metre)	3.2	3.2	3.2	3.2	3.2
Decking (Metre)	1.5	1.5	1.5	1.5	1.6
POI distance (Metre)	235	240	227	210	227
PPV (mm/s)	5.2	4.8	3.3	4.9	3.2
Passing size (mm)	557	460	466	491	483
Inter hole delay (MS)	20	8	12	20	16
Inter deck delay (MS)	4	2	3	4	3
MCPD (KG)	120	90	75	100	80

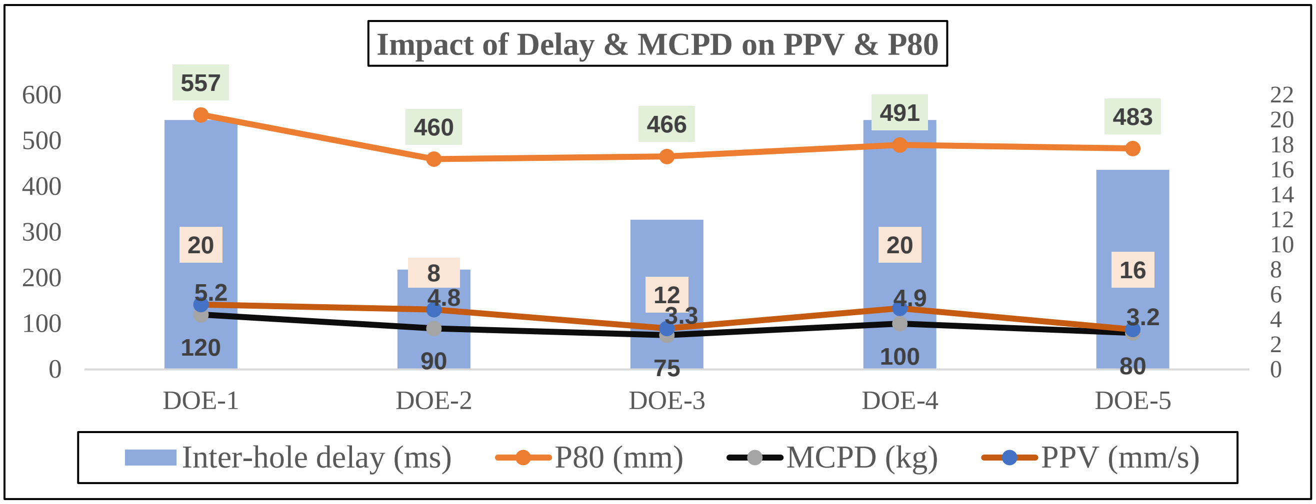
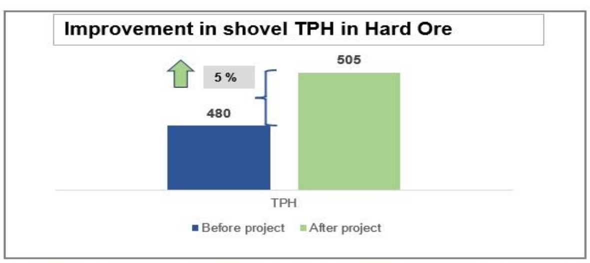


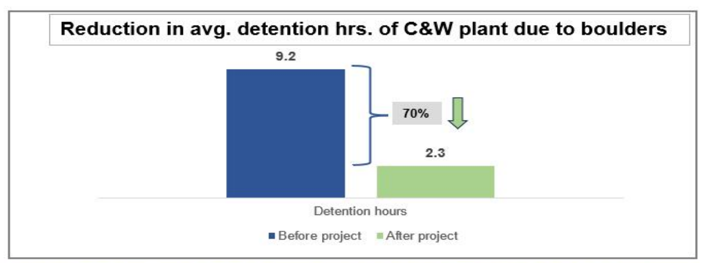
Chart 1: Blast Parameters of various design of experiments performed by varying the MCPD and delay timings.

7. Conclusion:

1. **Vibration Control** – achieved by decreasing the MCPD, increasing the inter charge/hole delays.
2. **Fragmentation Improvement** – achieved by squeezing the pattern (Burden and Spacing), increasing the MCPD and decreasing the inter charge/hole delays.
3. **Vibration Control and Fragmentation Optimization** – By squeezing the patterns, optimizing the MCPD and inter charge/hole delays vibration was kept in control while also improving the fragmentation of the blasted rock.
4. **Trial of Pilot hole drilling-** yielded good results in elimination of collar boulders & improving fragmentation.

8. Result:





1. Improvement in shovel TPH by 5%

2. Reduction in avg. detention hrs. of C&W plant due to big boulders by 70 %

3. Improvement in Fragmentation avg. P_{80} by 42% from the range of 0.85m to 0.49m

4. Improvement in blast induced ground vibration control to PPV values of less than 5mm/s

5. Elimination of the fly rocks.

-------End--------