STUDY ON OPTIMIZATION PARAMETERS OF DRILLING AND BLASTING

[*]D HUSSAIN [*], B RAMARAO [*], J SASI GOVARDHAN [*] , V HARI KALYAN[*], KUMAR SANJAY[@]

[*] B. Tech students, Department of Mining Engineering. Godavari Institute of Engineering and Technology, Rajahmundry, Andhra Pradesh, India.

[@] Asst. Professor, Department of Mining Engineering, Godavari Institute of Engineering & Technology, Rajahmundry, Andhra Pradesh, India

Abstract: Mining play's major role to development of nation, mining is defined as extraction of valuable minerals (or) ore from the earth crust for benefit of mankind in safe and economic manner. India is a developing country it needs valuable minerals to improve economic wealth. In India most of the mining operations are run by open cast mines. In open cast mining work is mainly involves drilling and blasting operations. Mostly drilling and blasting operations are followed except in smooth rock, where bucket wheel excavator [BWE] used. The main problems a raise in drilling and blasting are high capital investment, time taking process and less powder factor. This loss depending on parameters like geological conditions of the mineral, nature of ground, strength and type of drill bit to be used in drilling. And drilling pattern, explosives used for blasting also involved. It concludes optimization of drilling and blasting necessary to improve the powder factor, production rate, improving fragmentation of rock, reduction of ground vibration, reduce cost of drilling and blasting. The main optimization technique achieved by help of following factors. Those are spacing, burden, bench height, drill hole diameter, depth of the drill hole and characteristics of explosives (VELOCITY OF DETONATION & DENSITY). In this work we studied on different types of optimization parameters and choosing the best techniques among the following techniques.

Index Terms - DRILLING, BLASTING, EXPLOSIVES, VELOCITY OF DETONATION.

I. INTRODUCTION

The mineral is mainly extracted by two methods open cast mining method and underground mining method. In India widely used method is open cast mining method. Drilling and blasting are key operations to mining to extract any type of mineral. In this topic we discuss mainly about optimization of drilling and blasting parameters to improve rate of production with minimum cost.

Drilling is the process of making a hole into the hard surface. When the successful drilling is carried out it is possible to do blasting successfully. Because the placing of explosive in the hole is requirement. Since the quantity of an explosive present in the hole is depends on drill hole specifications. And also, the depth of the hole and diameter of the hole plays an important role in blasting.

Blasting is the operation of breaking the rock into small number of pieces by using explosives. Blasting is used to removing of overburden as well as mineral deposit. And also, explosives used for blasting are very costly. It is necessary to minimize the cost for blasting and improve the optimum utilization of explosives.

Optimization means the action of making the best or most effective use of resources. Optimization of blasting involves in different type of factors related to rock, explosive, drill hole parameters and their layouts.

Objectives

The goal of the investigation is to decide a result of optimum blast techniques based on their parameters, as type of explosive, explosive quantity, blast pattern and drill hole information.

The main objective addresses towards:

1. To study the drilling methods and their machineries for effective drilling.
2. study of blasting parameters for better conditions.
3. The objective of this model was to determine the optimum bit diameter that meets the annual ore production.
4. A study of various optimization techniques for better result.

Need for study

Most of the economic mineral deposits occur in massive hard rock. These rock masses should be fragmented to obtain the valuables and separate the materials for further processing This process can be achieved by conducting of drilling and blasting. But sometimes these operations cannot give better results because some parameters effect the blasting results i.e., improper design of blast pattern, poor implementation of blast design in field work and poor use of explosives. So, these operations are eliminated with making of better blast design from old ones means optimize the blast designs for better results and improve productivity.

> ➢ *Factors Affecting the Drilling*
>   - Strength of The Rock:
>   Type of drill bit used and penetration of drilling is mainly depending on strength of the rock.

- Hardness of the Drill Bit:
  It reduces the time of drilling and selection of improper drill bit may result that cause deviation of hole and also, we should not make a proper hole.
- Geological disturbance:
  Creates deviation of hole. Method of drilling… The following are the types of drilling. They are percussive and rotary and rotary percussive drilling. Method of drilling is depending upon the hardness of the rock.

➢ *Factors Affecting the Blasting*

- Spacing And Burden:
  These are the main factors affecting blasting to get maximum output and reduce the cost of blasting.

- Watery condition of drill hole:
  Iin case any water present in the drill hole that will reduce the performance of explosive.

- Diameter of Drill Hole:
  Large diameter of hole reduces the powder factor and also increase the cost of explosives.

- Characteristics of Explosives:
  Higher **velocity of detonation** of the explosives will give max output. Density of explosives also play key role in blasting.

- Height of The Bench:
  If the height of the bench is less, there is chance to yield.

- Depth of The Hole:
  It is also playing a key role in blasting performance. In case of depth of the hole is more there is a chance of formation of toe. And also, in case height of the bench is less   we will not reach our production in Intime.

Classification of Drilling Systems:

The drilling machines used in opencast mining can be classified in the following ways:
I. Depending upon the principle of working:
    a) Percussive drilling
    b) Rotary drilling
    c) Rotary-Percussive drilling
II. Depending upon the type of Prime mover:
    a) Used Fuel driven drilling machines
    b) Electrically driven drilling machine
III. Depending upon the means of power transmission:
    a) Pneumatically operated machine
    b) Hydraulically operated machine
    c) Electrically operated machine
        i.   Hydraulic system
        ii.   Pneumatic system

Percussive Drilling Method:
It is the one of the oldest method drilling. In this method rock is broken by chipping action.
The percussive drilling method sub-divided into two types:
a) Drilling by rigid rods. b) Rope drilling. (It is also known as cable drilling or churn drilling).
The hole is drilled by the striking a number at shot in intervals on the rock by a chisel type tool and between the blows the tool rotated slightly. The rods are made up with nickel and chromium, or high carbon steel. This method is applicable to maximum depth of 300meters. Rising and lowering   the rods of square cross section and circular cross section is done by retaining key and bulldog safety clamp respectively.

Rotary Drilling Method:
In rotary drilling the rock is broken by crushing action. In this drilling hallow drill rods of steel or aluminium are used. Rotation of drill rod is through gearing driven by a prime mover at the surface. In this method it is possible drill large diameter of holes in between [250-300mm]. The broken rock or cuttings are cleared by pumping water under high pressure in drill hole. This drilling method is applicable to maximum depth of 3000m [diamond drilling].
The following are the types of rotary drilling methods

1) Drilling by saw toothed cutter.
2) Drilling by tricone rock roller bit.
3) Drilling by diamond drill bit.
4) Drilling by chilled shots.

Rotary-Percussive drilling Method:

In this drilling method the rock is broken by the action of rotation of drill rod and penetration of drill bit done in simultaneous process.

1. **Percussion**: In drilling machine, the piston inside the rock drill blows the rear end of the drill rod or bit itself and produces the shock waves that are transmitted to the drill bit through the n drill rod (in top hammer) or directly to the bit (in down the hole hammer).

2. **Rotation**: The Rotary mechanism rotates the drill rod (in top hammer) or rotates the drill tube or rotates the hammer (in DTH). By this operation, the drill bit is turned to so many times. Due to this the impacts can be produced on the rock in different positions.

3. **Feed or Thrust load**: The feed force is required to keep the rock in contact with the drill and the drill bit. This ensures that the maximum impact force is transmitted from the piston to the rock.

4. **Flushing**: Flushing is used to remove the rock cutting from the drill hole and cool the bit. Flushing medium Air, water, fog or foam rod is forced down the drill hole by a hole in the flushing hole and drill bit.

In this paper, a hypothetical open pit copper mine is considered, which needs to produce 30 million tons of waste and 25 million tons of ore based on its annual planning. This mine works 340 days a year, on which the drilling and blasting operations can be carried out. Thus, the time scale of the dynamic model is set as these operational days. Some of the other technical and economic parameters of this mine are mentioned in Table 2. In the model, bit diameter is a primary parameter that affects both drilling and blasting operations. This happens through the penetration rate and its dependent parameters such as pulldown force and rotational speed and through the blasting geometrical parameters like burden, spacing drill hole depth, etc., respectively.
Accordingly, the objective of the model is to find the optimum bit diameter. In addition, simulation is only performed for the ore products of the mine (30 million tons per year).
To evaluate the outcome of the model, simulation and optimization are carried out under different conditions:

      (1) Simulation with arbitrary bit diameters in deterministic conditions.
      (2) Optimum bit diameter in deterministic conditions.
      (3) Optimum bit diameter in uncertainty conditions.

The optimization process will be carried out to find the optimum bit dimeter while fulfilling all of the above-mentioned criteria. As the final result of the optimization model shows, the bit diameter of 8.333 in. is capable of achieving the annual ore production of 30 million tons. Table2 depicts other parameters in the optimization runs. In graph also shows a comparison between the total blasting production and the total costs of drilling and blasting operations in three different bit diameters in above tables.

One of the main goals of this research was to present a new method for modelling drilling and blasting operations. While previous research paid attention mostly to a specific part of these operations, the proposed model enables us to consider all technical, economic and environmental parameters that were built as a system dynamic model. The major advantages of using such a dynamic model are:

      (1) The capability of monitoring and measuring the changes in parameters and variables through time.
      (2) The possibility to control dynamic changes in the system, where each part can simultaneously affect the other.

As a case study for evaluating and making the model functioning, a copper mine was considered. The objective of this model was to determine the optimum bit diameter that meets the annual ore production. The most critical reasons for choosing this parameter were. The bit diameter is the most direct and determinative parameter in both drilling and blasting operations. In fact, it has a direct influence on the penetration rate and burden in drilling and blasting operations respectively (Fig.1).
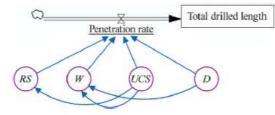

Figure-1 Penetration Rate Of Drilling

The below information is referred from H.Abbaspour (2018).

Table 1: Technical, economic and environmental parameters for the bit diameter 8 and 9 in.

Parameter	Bit diameter 8 in.	Bit diameter 9 in.
Burden (m)	5.08	5.71
Spacing (m)	7.62	8.5
Depth of drill hole (m)	12.7	14.29
Stemming (m)	3.556	4
Join drilling (m)	1.524	1.715
Rock tonnage per one drill hole (m^3)	1.082	1.54
Number of drill holes	19,628	17,447
Total blasting production (Mt)	23.78	30.02
Bit cost component (₹ /ft)	17.17	20.60
Drilling operation cost (M₹)	1.475	1.767
Blasting operation cost (M₹)	4.936	6.247
Total drilling and blasting costs (M₹)	6.41	8.01
Explosive mass in one drill hole (kg)	237.2	337.7
Explosive volume in one drill hole (m^3)	0.29	0.42
Total explosive mass (ton)	4656	5893
Explosive CO emissions (kg)	158,309	200,360
Explosive NOx emission (kg)	37,249	47,144
Explosive SOx emission (kg)	4656	5908

Table2: Optimized technical, economic and environmental parameters of the bit diameter 8.333 in.

Parameter	Bit diameter 8.333 in.
Burden (m)	5.292
Spacing (m)	7.937
Depth of drill hole (m)	13.23
Stemming (m)	3.704
Join drilling (m)	1.587
Rock tonnage per one drill hole (m)	1.222
Number of drill holes	21,914
Total blasting production (Mt)	3.000
Bit cost component (₹/ft)	31.95
Drilling operation cost (M₹)	3.174
Blasting operation cost (M₹)	6.228
Total drilling and blasting costs (M₹)	9.402
Explosive mass in one drill hole (kg)	268.11
Explosive volume in one drill hole (m^3)	0.335
Total explosive mass (ton)	5.875
Explosive CO emissions (kg)	199,760
Explosive NOx emission (kg)	47,002

The optimization process will be carried out to find the optimum bit dimeter while fulfilling all of the above-mentioned criteria. As the final result of the optimization model shows, the bit diameter of 8.333 in. is capable of achieving the annual ore production of 30 million tons. Table 2 depicts other parameters in the optimization run.

Figure-2

(a) Total blasting production   (b) Total drilling and blasting costs
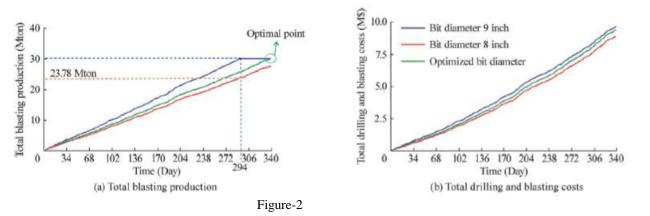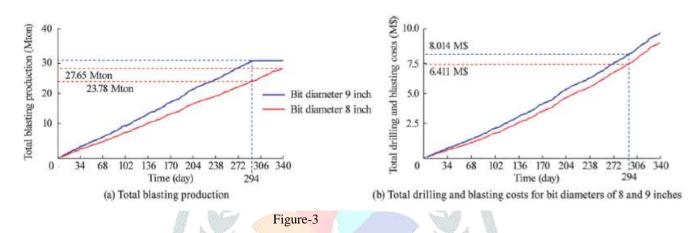
Fig. 2 Also shows a comparison between the total blasting production and the total costs of drilling and blasting operations in three different bit diameters (8, 9 and 8.333 in.).

(a) Total blasting production   (b) Total drilling and blasting costs for bit diameters of 8 and 9 inches

Figure-3

As a result of the bit diameter optimization in a deterministic way, it was concluded that a bit diameter of 8.333 in. can cover the annual production of 30 million tons of ore in one year (340 days). Other attempts of bit diameter (i.e., 8 and 9) failed due to the following reasons:

(1) In spite of lower total operational costs through drilling by the bit diameter of 8 in., the annual production of the mine was not fulfilled (Figure-3).

(2) Although the bit diameter of 9 in. could reach the annual plan even earlier than the 30 million tons of ore production (Figure-3 and table-1).

Conclusion

In this research, the system dynamic method for modelling drilling and blasting operations was proposed. This model could efficiently connect and evaluate all the technical, economic of these operations. In addition, the changes in parameters through the simulation period (one year of production), especially in case of the total production and costs were measured. An optimization process for bit diameter in two different conditions, deterministic and uncertainties was carried out. It was shown that the optimum result can be totally different in the case of deterministic (8.333 in.)

References

[1] Kahramana S, Bilginb N, Feridunoglub C. Dominant rock properties affecting the penetration rate of percussive drills. Int J Rock Mech Min Sci 2003;

[2] Afeni TB. Optimization of drilling and blasting operations in an open pit minethe SOMAIR experience. Mining Sci Technol 2009;

[3] Hoseinie SH, Ataei M, Osanloo M. A new classification for evaluating of rock penetrability. Int J Rock Mech Min Sci 2009;

[4] Tosun A, Konak G. Determination of specific charge minimizing total unit cost of open pit quarry blasting operations. Sci Technol 2009;

[5] Hustrulid W, Kuchta M, Martin R. Open pit mine planning and design. Boca Raton: Taylor & Francis group; 2013.

[6] Bilim N. Determination of drill ability of some natural stones and their association with rock properties. Sci Res Essays 2011;

[7] Saeidi O, Torabi S, Ataei M, Rostami J. A stochastic penetration rate model for rotary drilling in surface mines. Int J Rock Mech Mining Eng 2014;

[8] Afum BO, Temeng VA. Reducing drill and blast cost through blast optimization case sudy. Ghana Mining J 2015:

[9] Bowa VM. Optimization of blasting design parameters on open pit bench a case study of Nchanga open pits.Int J Sci Technol Res 2015;

[10] Taheri A, Qao Q, Chanda E. Drilling penetration rate estimation using rock drill ability characterization index. J Inst Eng (India) 2016;