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A Study of a Blasting Operation in Open Pit Mine With GPSS/H Simulation Program

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Abstract

The economic analysis and the use of explosives is an important part of blasting operations in open pit mining. Explosives are energy and the efficient use of this energy is a major factor in keeping rock blasting costs under control. The degree of fragmentation and movement obtained is directly related to the amount of explosives used in operation and the delay array sequencing of firing blasthole. For economic reasons, blasting must be both well planned and be accurately executed using minimum amount of explosives. If the blast sequence is correct, less explosives will be required at a single time. In this study, a simulation model is developed by using GPSS/H simulation software program for a small open pit mine with 11 blasthole operation drilled out at a given array pattern to determine the out of sequence firing (OOSF) and crowding as ms delays by varying the scatter in mean delay time while assuming a predefined value for crowding as ms delay. The simulation results and the interpretations of them for a given mine site provides the optimal sequencing and the scatter of the selected blasting agent.

Key words

Open Pit Mining, Blasting Patterns, Discrete-Event System Simulation, GPSS/H Software

1. INTRODUCTION

Drilling and blasting are two of the major unit operations in most open pit mines. The main goal for these operations is to optimize rock fragmentation that may cost as high as 25-30 % of the total operating cost in open pit mining. Efficient blast design along with proper choice of explosives can produce better fragmentation with associated lower operating cost compared to the blast designs and explosives under adverse conditions. Delay patterns and varying the blasthole array to fit the natural excavation topography allow for more efficient use of the explosive energy in a blast. Benches may be designed and carried out with more than one face so that simple blasting patterns can be used to remove the rock materials. [1].

A face (or bench in an open pit mine) about to be blasted consists of numerous holes filled with powder (or suitable blasting agent). The holes are blasted in sequence to allow for maximum fragmentation and detonation. For example, if the holes were drilled in concentric circles, the sequence of the blast would be from the innermost ring to the outer ring. Each of the holes in each circle would ideally have the same delay. To ensure this sequencing, delay detonators are used. The length of this delay is given by the manufacturer's specification in milliseconds (ms).

For economic reasons, the blast must be both well planned and be accurately executed using the minimum amount of explosives. If the blast sequence is correct, less explosives are required at a single time.

Typical delays, as given by manufacturers, might be for 200 ms, 300 ms, 1500 ms etc. However, in practice, these delays tend to be average values and the actual delay times are stochastically distributed. In this example, the delay times will be assumed to be estimated from a normal distribution. Figure 1 shows a typical face about to be blasted. It is of concern both the holes are fired in proper sequence and that they do not fire too close in sequence. If the holes fire out of sequence, this is known as “Out-of-Sequence-Firing” (OOSF), if they fire too close together, this is known as “Crowding”. Figure 2 shows an arrangement of a few holes. Those numbered 1, are to be donated at the same time and so have a delay of 200 ms. those numbered 2 are to be fired next and they have a delay of 300 ms.

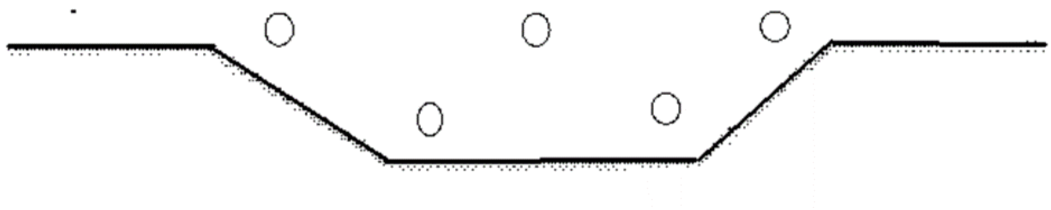

Figure 1. A typical face to be blasted of firing for holes

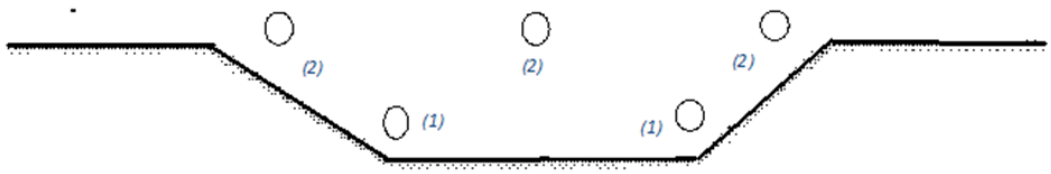

Figure 2. Arrangement for firing of blast holes

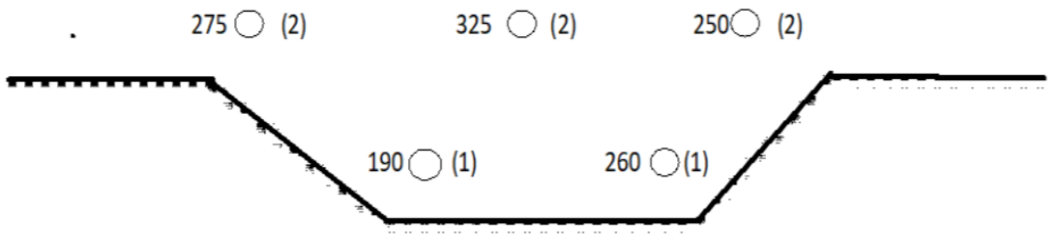

Figure 3. Actual delay times for blast holes

2. MATERIALS AND METHODS

The listing of the program is given as MINEBLAST.GPS. GPSS/H is a discrete-event systems simulation language widely used by many academicians and commercial users and it uses process-interaction approach to modelling. The modeler specifies the sequence of events separated by lapses in time which describes the manner in which objects flow through a system. Models are developed in text files in GPSS/H and compiled into memory and executed [2]. It is considered in this study a case study problem which consists of a series of shots as given by the arrangement in Figure 4.

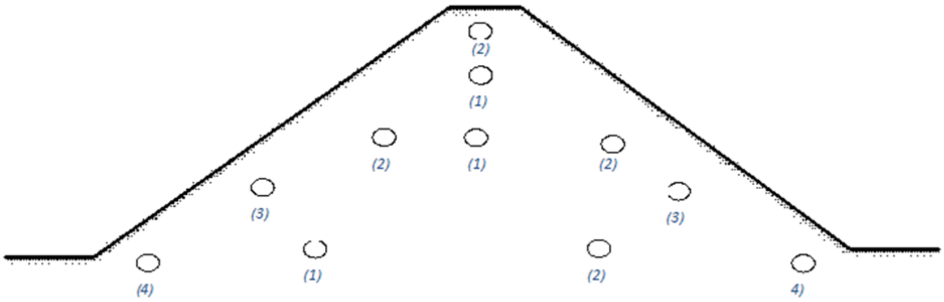

Figure 4. Arrangement of firing for sample holes

As can be seen, there are 11 holes to fire in 4 sequence which are numbered (1), (2), (3) and (4). The planned sequence is first the three holes labelled (1), next the four holes labeled (2), then (3) with two holes, and finally, (4) with 2 holes. The delay times are sequentially, 200 ms, 400 ms, 600 ms and 1000 ms for this sequence.

Actual delay time is assumed to be mean time with a standard deviation of 12 %. If blasting takes place in sequence, but within 30 ms of another hole, crowding is assumed to take place. Because of the statistical nature of the delay times, OOSF and crowding will only take place in subsequent hole blasts, i.e. between holes (1) and (2), (2) and (3) and (3) and (4).

3. RESULTS AND DISCUSSION

The simulation was done for 200 simulated blasts [3]. There were 11 holes and, because of their arrangement, each time a simulation was done, there had to be 24 tests for OOSF and crowding. This first sequence (1) consisted of 3 holes. Their blast times were compared to the second sequence of holes (2) consisting of 4 holes. There were 12 tests done here. However, the next sequence (2) for 8 total comparisons. Finally, sequence (4) consisted of 2 holes and each of these was compared to the sequence (3). There were 4 such comparisons. Thus the total of 24 (12 + 8 + 4). The simulation was performed for varying values of the scatter. 1000 simulated blasts were performed. The mean delay times are as shown in Figure 3 and the standard deviations were taken starting at 9 % of these values. Crowding was assumed to take place if the delay was 30 ms or less. The simulation was the repeated with std. dev. increased by 1 % until it was 20 % of the mean. Input values and prompt are:

Input the time for crowding as ms delay

<< 30>>

How many blasts to simulate for

<<1000>>

Input the scatter as a percent

<<9>>

The simulation results are given in Table 1. The interpretation of the results depends on the particular mining situation and how many OOSF's are allowed. If these are to be no more than, say, 0.5 %, then the detonators need to have a standard deviation of less than 13 % of the mean as this gave 100 OOSF's. There were 24.000 possible OOSF's and 0.5 % of this is 120. For a standard deviation of 14% of the mean, there were 140 OOSF's.

Table 1. Results of Simulation for Case Study Problem

% Scatter Std. Dev.	Out of Sequence Firings	Crowding
9	5	20
10	15	32
11	35	62

12	60	77
13	100	89
14	140	110
15	182	133
16	242	139
17	298	164
18	255	195
19	412	233
20	484	277

4. CONCLUSIONS

A small case study example problem is presented for blasting pattern in open pit mine where a series of shots as given by the arrangement. Drilling and blasting practices used in many open pit mines are mostly designed by the intensive grade-control practices that have developed as a result of complex grade distributions found in these ore bodies.

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