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Research Paper

Numerical Analysis of the Pile Movement Resulting from Rock Blasting in Open Pit Mines

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Abstract: Pile movement is one of the rock blasting outcomes that, considering the type of haulage machines, has a direct effect on the efficiency of the loading process. In this study, using UDEC discrete element software, the pile movement of fragmented material caused by the blasting operation is modeled. Since UDEC is not capable of modeling the whole process of rock blasting, to accurately model the pile movement of fragmented material, the damping coefficients must be changed in a way to allow the move freely out of the split blocks after the blast, be modeled. The numerical modeling results show that implementing a negative exponential function with three (the initial, threshold, and power) eigenvalues, as the fish-function to the damping coefficient, can model the results pile movement. With the help of this damping function, three blasting blocks with one and two rows of blast holes were modeled. The results of these modeling show that the pile movement for the two rows of blast holes depends on the inter-row delay time, and for the delay times of 17 ms and 50 ms, the maximum horizontal movement of the pile was 30 m and 55 m, respectively. These values show good agreement with the values measured in an actual blast operation. The results of this study show that by changing the negative exponential function eigenvalues defined for damping, the velocity of the fragmented blocks, the displacement, and the geometry of the pile, could be modeled. This shows the capability of the discrete element method in the modeling of the results of rock blasting.

Keywords: Blasting, Numerical modeling, Damping coefficient, Fish-functions, Pile movement.

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INTRODUCTION

To investigate the numerical modeling capability of the fragmented rock mass and pile movement by blasting using the discrete element method, the UDEC software has been used. This software can model the types of contacts between rock blocks that are next to each other due to discontinuities, and future contacts between these blocks that rotated or displaced after applying forces and come close again. In addition, the UDEC software can model dynamic loadings such as blasting and earthquakes. Therefore, by combining these two properties, an acceptable analysis of how the fragmented rocks move after the blasting can be obtained, which can be very helpful in diluting minerals (especially at the boundary between the ore and waste). It is also possible to determine the final shape of the pile movement, which plays a significant role in the efficiency of loading and hauling operations. In general, methods of predicting and controlling the results of blasting operations are divided into three general categories: analytical studies, field, and laboratory studies, and numerical modeling. Due to time and cost savings, high flexibility, and continuous development of computer systems, although numerical modeling has its drawbacks and limitations, it has a particular share in predicting the results of blasting operations [1]. The main categories of numerical modeling that have been done till now can be divided into continuous [2-4], discontinues [5-7], and combined [8,9] logic. Each type of mentioned modeling the rock fragmentation by blasting has its advantages and limitations, and none of these methods can simulate the whole process and results. In this paper, using rectangle discontinuities the area of the blasting is divided into pre-fractured rocks, by applying the dynamic loads of the blasting operations is modeled for single and two rows of the drilled hole and with different inter-row delays time. The results of this study show that by applying some simplifications and defining a time-variant of the damping coefficient, the UDEC software can simulate the pile movement caused by blasting operation with acceptable accuracy.

METHODS

In the first step, to model the pile movement caused by blasting operations, a hypothetical rock slope with a height of 15 m and a width of 19m with a slope of 75° has been modeled in the UDEC discrete element software. It is assumed that a row of blast holes with a depth of 17m (including 2m of sub-drilling), with a diameter of 250mm and a stemming length of 3m was drilled. The non-reflective (viscous) boundary conditions have been used to avoid unwanted reflection of waves from the model boundaries. The area of blasting has been pre-fractured using two perpendicular sets of joints with statistical variation in spacing, in which that the size distribution of produced particle is similar to the reality. The size of generated particles has been calculated, and the semi-log graph of these particles generated using existing fish functions in UDEC logic. As the charge is detonated with a specific velocity, the blast hole is divided into several cylindrical parts that detonates consecutively so that the total time of loading of the whole cylinders equals the actual time of the blasting process is a real blast hole. It is assumed that the detonation velocity of the charge is 4500m/s, and for the 14m of the charge length, the whole time of the detonation process for such a hole equals 3.11ms. On the other hand, based on the mathematical behavior of the pressure-time dynamic pulse proposed by Yoon and Jeon (2009), for the rise time of 28μs, the duration time of the pulse has to be 222μs. So, in each step of the dynamic loading (for the mentioned time duration), considering the detonation velocity, the height of each small cylinder has to be 1m. The rise time of the dynamic pulse loading is calculated as the time required to detonate the cross-section circle of the cylinder (considering the charge radius of 125mm and detonation velocity of 4500m/s). As the mechanical damping in UDEC can affect the consequences of the dynamic process, while the pile movement needs different damping coefficients to move freely, a time-variant fish function is proposed to model the whole process of the rock blasting and the pile movements. The results of this combination of dynamic loadings and time-variant damping coefficient show a real process of pile movement. Based on the obtained results from the first step, in the second step, a numerical model of two rows of blast holes is modeled, and the effect of inter-row delay times is investigated. The results show that the shape of the final pile is a function of inter-row delay time and separation and displacements of fragmented rocks have reverse relation with it. The results show a good agreement with the actual blasting operations. Figure 1 shows the geometry, boundary condition of the numerical modeling. The size distribution and dynamic pulse pressure for modeling blast loading showed in Figure 1.

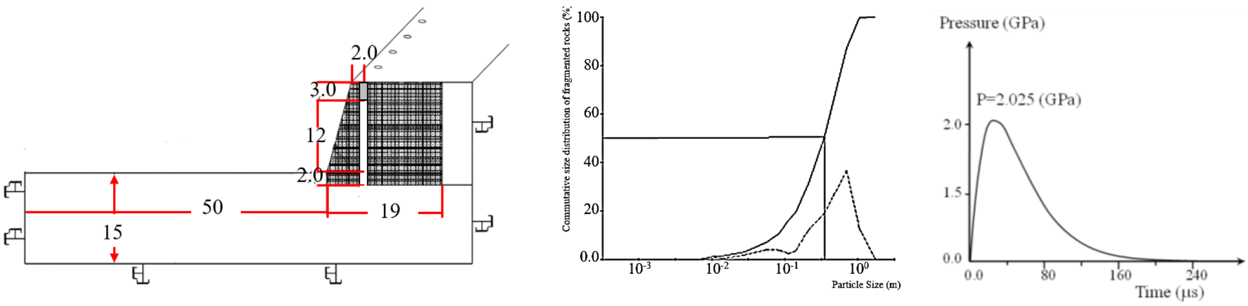


Figure 1. Model geometry, boundary conditions, size distribution, and blast puls loading in numerical modeling using UDEC

FINDINGS AND ARGUMENT

Numerical modeling is one of the best ways to model the high strain rate process such as blasting. There are several methods to modeling this process, but with some degrees of simplifications, the discrete element method used in UDEC software can simulate the combination of the dynamic loading, rock fragmentation, pile movement, and ground vibration caused by blasting operations. As the results of this study show, the step-by-step dynamic loading of blasting operations can simulate the actual dynamic loading of blast holes considering the direction of detonation. The crossing two perpendicular sets of the joint can model the size distribution of rock fragments, with the help of implementation of a fish function UDEC can count, measure, and draw a size distribution graph of generated rock fragments with above mentioned fictitious joints. One of the valuable features of numerical modeling with UDEC software is the capability of substitution of constant values with time-variant quantity using fish functions. The value of this feature becomes clear while modeling the actual dynamic process such as pile movement. This is while choosing any constant value of the damping coefficient is not allowed the model to behave real. The results of this study dedicated that with the help of time-variant values for mechanical damping coefficient, the pile movement process of the fragmented rock can be modeled in UDEC software. Figure 2 shows the final condition of the pile for the field experiment of rock blasting. Figure 3 shows the numerical model output of 2 rows of blasting with inter-hole delay times of 17ms and 50ms.

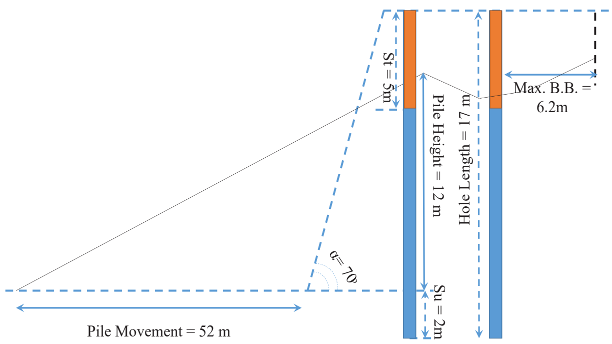
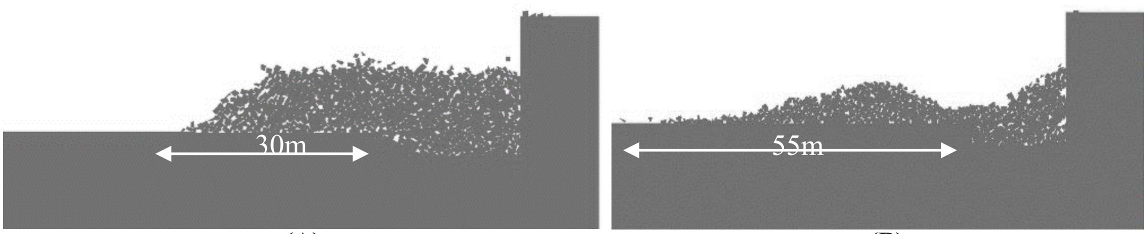


Figure 1. The final position of fragmented rocks after the blasting in the field experiment



(A) (B)

Figure 3. The final movement of fragmented rocks for two rows of blasting with the inter-row delay times of **A:** 17 ms and **B:** 50 ms

CONCLUSIONS

The movement of the fragmented rocks caused by blasting operations and the estimation of the grade distribution within the pile become of great importance in the efficiency of the loading machines and the blending and dilution of the mineral. There are various methods for predicting blasting results, among which numerical modeling has become more popular among researchers due to its time and cost savings and high flexibility. In this study, using the orthogonal artificial joints algorithm, the range of the blasting block is broken into pieces and their semi-log graph of cumulative size distribution is calculated and scattered by the fish functions in the UDEC software. Since this software cannot model the behavior of explosion gas products, a pressure-time pulse has been used to model the dynamic loading of blast shock waves. It has been tried to use step-by-step loading similar to field conditions. The results of this study show that by changing the values of the negative exponential function, a wide range of displacement results of the fragmented rock mass caused by blasting can be modeled. Based on the results of numerical modeling, the maximum horizontal displacement of the fragmented rocks for two rows of blast holes that with 17ms and 50ms inter-row delay times, is 30m and 55m, respectively. On the other hand, in a field blasting experiment, the maximum horizontal displacement of 52m was measured for the inter-row delay of 50 ms, which indicates the accuracy of numerical modeling in estimating the motion of the fragmented mass. Based on the results of this study, by accepting some simplifications and assumptions, it is possible to model pile movement caused by blasting and its final shape and grad distribution in the UDEC discrete element software.

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