The 55th International October Conference on Mining and Metallurgy
15 - 17 October 2024, Kladovo, Serbia
https://ioc.irmbor.co.rs

DOI: 10.5937/IOC24175R Original Scientific Paper-Mining

POSSIBILITY OF STOCHASTIC METHODS APPLICATION ON ORE DRAWING FOR BLOCK CAVING MINING METHOD

Mladen Radovanović[1a], Ivana Radovanović[1b], Dragan Zlatanović[1c], Milivoje Zlatić[1d], Dejan Petrović[1e], Jelena Ivaz[1f]

[1]Technical Faculty Bor, University of Belgrade, V.J. 12, 19210 Bor, Serbia
[1a] mlradovanovic@tfbor.bg.ac.rs, https://orcid.org/0000-0002-0703-2780;
[1c] dzlatanovic@tfbor.bg.ac.rs, https://orcid.org/0000-0002-1095-1913;
[1d] zmilivoje1@gmail.com,
[1e] dpetrovic@tfbor.bg.ac.rs, https://orcid.org/0000-0001-8588-2046;
[1f] jivaz@tfbor.bg.ac.rs, https://orcid.org/0000-0001-9263-6804

Abstract

In the current conditions of exploitation, when the content of useful components is decreasing, and the deposits are lying at greater depths, the need to apply mass and large scale mining methods inevitably arises. In the group of high productive methods, block caving takes very important place. Block Caving is a mass, large scale mining method which is usually used for exploitation of low-grade ores. Efficiency of these mining method depends on quality of ore drawing process. Research of ore drawing process has great influence on mining methods parameters and consequently on ore recovery and dilution. The research of these processes is possible by applying different modeling methods such as stochastics methods. The simplicity and estimation features of stochastics methods is used for creating models for gravity flow of materials and determination of ore drawing parameters which is later can be used for determination of optimal parameters of mining method.

***Keywords**: ore drawing, stochastic methods, Block Caving*

1. INTRODUCTION

Caving methods include a large number of very important mining methods, which are applied for the exploitation of ore deposits. Large scale caving methods are used mainly for the excavation of large steep ore deposits with greater thickness [1]. This group of mining methods is characterized by high production and productivity, with a high degree of mechanization and automation of the exploitation process. Because of all this, as well as because of the lower development ratio compared to mining methods from other groups, caving methods enable mining with the lowest costs of obtaining ore, which is why they are used primarily for the exploitation of deposits with low grade ore.

Block Caving mining method is based on the principle that the ore, after undercutting on the appropriate surface, collapses by itself, thanks to the existence of one or more crack systems in the ore massif. The efficient application of block caving is can be achieved only if caved ore is with appropriate granulation, which enables satisfying ore drawing without jams in the drawpoints and frequent secondary crushing of oversized pieces of ore. The block caving methods are undeniably the cheapest methods of mining, so their application is a priority in all cases of the exploitation of low grade ores.

The application of this mining method is favored by the natural cracking of the ore. The greater thickness of the ore body is necessary because, to ensure successful self-caving of the ore, the deposit must be undercut on a larger surface where the formation of a hangouts will be avoided and stop further self-caving of the ore.

Ore drawing process is important for determining the basic parameters of mining method. For the application of caving methods it is very important to determine proper distance between drawpoints as well as their mutual arrangement [2]. The ore drawing process of caved ore has been the subject of numerous researchers on physical models in laboratory conditions, as well as in natural conditions, whether it is experimental stopes in a pit or regularly production stopes on the excavation of parts of the deposit in underground mine. The research of these processes is possible by applying different modeling methods (stochastic, numerical modeling, etc.) as well as by applying appropriate softwares [3].

The basis of stochastic methods for describing some phenomena are rules and probability. These methods are not based on a physical principle that mathematically gives the right results. Stochastic models for the analysis of the ore drawing process are based only on the principle of conservation of mass. Despite the weak basis, stochastic methods can be a very powerful tool for solving material flow problems, i.e. ore drawing. Possibility of application of these methods for estimation of ore drawing process is shown in this paper.

2. EXPERIMENTAL

In caving methods where the ore must be moved from its initial position to the drawpoint, a gravity flow analysis of the material being extracted is necessary. Given that ore dilution occurs during drawing process, it is necessary to estimate the degree of dilution for different drawing strategies in order to minimize the inflow of waste and optimize the ore recovery. Stochastic methods have proven to be a good methodology for this type of assessment.

The ore drawing theory is based on the established fact that when ore is extracted from a drawpoint, the ore is extracted from a space whose volume corresponds to the shape of a rotating ellipsoid, which we call the draw ellipsoid. In practice, the ideal shape of the draw ellipsoid is most often disturbed. Regardless of that, knowledge of these laws enables the ore drawing process to be designed and implemented as correctly as possible, allowing, at the same time, to determine numerous parameters and indicators of the mining method. The theoretical propositions of the ore drawing theory are primarily based on model tests in laboratory conditions.

Stochastic methods are tools for modeling outcome estimation by allowing for random variation in one or more inputs. When material is removed from the drawpoint, an empty space is created which is filled with the overlying material. The exact source of this material is unknown, so it is assigned a random location.

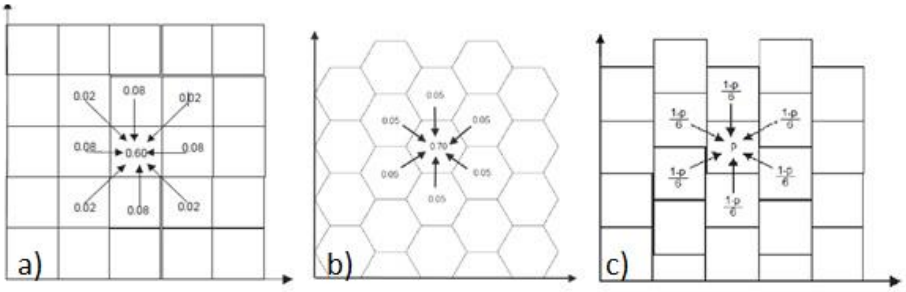

Figure 1. *Stochastic model grids a) Basic grid; b) Hexagonal grid; c) Cube geometry grid*

Figure 1a shows a grid that describes this concept. When some material is removed from the cell below the center of the grid, the empty space is filled from any of the nine cells above. This process is random, which makes stochastic models ideal for this type of problem solving. The grid shown in the figure does not correspond to the axisymmetric nature of the problem. Therefore, Figure 1b shows a grid with hexagonal cells, which is more suitable for the analysis of gravity flow of materials, because it can model the axisymmetric problem. The disadvantage of this type of grid is the shape of the cells, which complicates the calculation. Figure 1c shows a grid that represents a combination of the first two variants, that is, this grid combines a simple cube geometry and a circular location of a hexagonal prism. In Figure 1c, p represents the probability that the empty space resulting from the drawing of the volumetric excess from the drawpoint will be filled with material from the cell above, while the expression (1-p)/6 represents the probability that the empty space will be filled with material coming from one of the cells which are located around the central cell [4].

Based on the formed grids, 2D and 3D models of the gravity flow of materials can be created, which can be used for the analysis of ore drawing process for the appropriate design of the mining method.

3. RESULTS AND DISCUSSION

Most of the problems in mining are three-dimensional, however some processes can be represented simply through two-dimensional models. The application of stochastic methods in 2D modeling in this case boils down to Pascal's triangle which can be used to clarify how probability can be used to estimate the gravitational flow of materials. This concept was extended to 3D modeling (Pascal's cone) of gravity flow of materials.

By applying this concept of 2D modeling, it is possible to estimate possibility of a given cell to be affected by the ore drawing process. Figure 2a shows a cross-section of an excavation block with one drawpoint for different values of probability p. Probability p actually represents probability of material movement during ore drawing. In both cases, the same amount of material is removed from each drawpoint [4].

The width and height of the draw ellipsoid depends on the parameter p. For larger values of the parameter p, the ellipsoid has a smaller width, while with a decrease in the value of the parameter p, the width of the highlight ellipsoid increases. In this case adopted values for parameter p was 0.7 and 0.4.

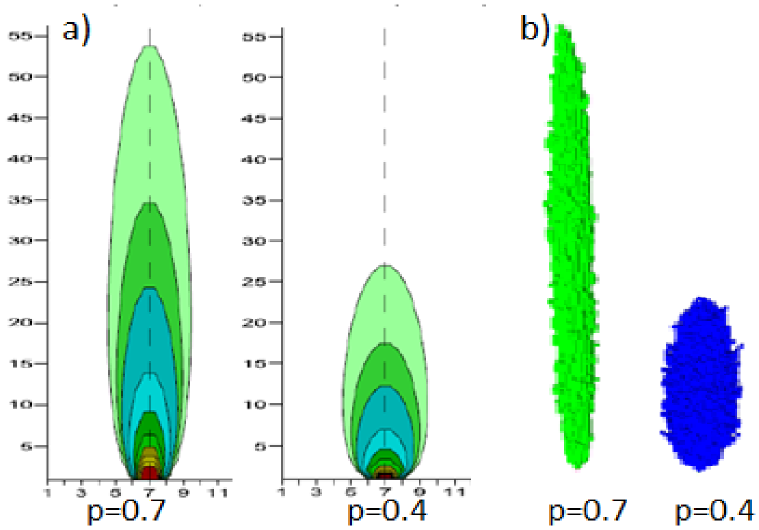

Figure 2. *Width of draw ellipsod for different values of probability p a) 2D model; b) 3D model*

In 3D modeling, the process can be observed through an inverted Pascal's cone (Figure 2b). The analysis starts from a cell with a probability of 1 (the material is removed from there), while the next layer above represents the probability that one of the cells will fill the resulting empty space below. With upward movement, more cells are included in the calculation, and the width of the interaction between cells is controlled by the probability value p. Also in 3D modeling, it is possible to estimate the width of the draw ellipsoid for different values of p, as shown in Figure 3. In the graph shown in the figure, the width is expressed in the form of the number of cells that are influenced by the movement of the material, and not in the actual distance measured in meters [4].

In these types of stochastic models, it has been shown that the cell size has a great influence on the obtained results. Therefore, the choice of cell size must be made taking into account other parameters in the model in order to be able to reproduce the phenomena that are actually observed.

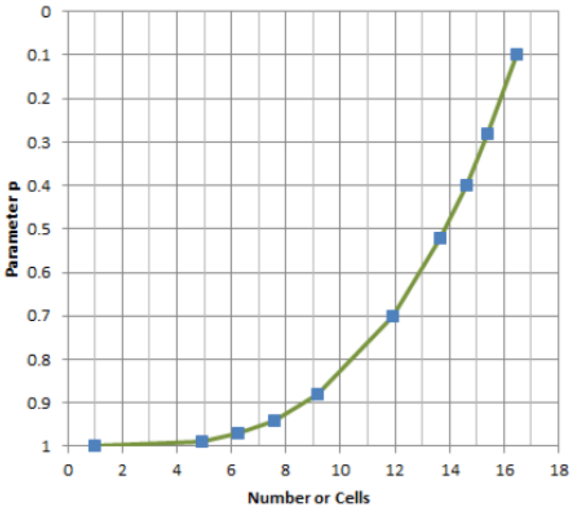

Figure 3. *Graph of the draw ellipsoid width related on the parameter p*

The parameter p affects the width or diameter of the draw ellipsoid in the model (expressed by the number of cells, not the width in meters). If the width of the draw ellipsoid is known, it is possible to choose the cell size and define the parameter p to be used when creating the model. The question remains how to relate the state of the rock mass or other observed behavior to the parameter p in order to create a model that would represent the actual gravity flow of the material.

There are some guidelines for correlating the observed material behavior with the width of the draw ellipsoid and this can be used to define the parameter p for a given cell size (using the graph in Figure 3). The process of estimating the width of an ellipsoid is based largely on experience and observation, and less on a robust formulation involving material properties.

4. CONCLUSION

The effectiveness of block caving method depends on the ore drawing process. Ore drawing depends primarily on the adopted parameters of excavation blocks (stopes), as well as on the type of facilities for drawing of ore and their mutual distance and position. In order to define the optimal parameters of the mining method, it is necessary to perform an analysis of the ore drawing process, which can be achieved by modeling.

In this paper it is shown that by applying stochastic methods, appropriate models can be created for the analysis of the gravity flow of materials, that is, stochastic modeling can be applied for research of ore drawing process. The simplicity and reliability of these methods enables the creation of stochastic models for ore drawing analysis, and the obtaining of appropriate results that could be further used for defining the parameters of the mining method for exploitation of ore. In this way, the parameters of the mining method would be defined, which would achieve maximum ore recovery with optimal ore dilution and enable economically profitable mining.

REFERENCES

[1] D. H. Laubscher, ‘Cave mining – the state of art’, The Journal of The South African Institute of Mining and Metallurgy, October 1994, p. 278-293.

[2] R. Kvapil, Gravity Flow in Sublevel and Panel Caving – A Common Sense Approach, Lulea University of Technology Press, Lulea, Sweden, 2004.

[3] R. Castro, F. Gonzalez, E. Arancibia, Development of a Gravity Flow Numerical Model for the Evaluation of Drawpoint Spacing for Block/Panel Caving. J South African Inst Min and Metall. 109 (2009), p. 393-400.

[4] W. H. Gibson, Stohastic models for gravity flow: Numerical considerations. Proceedings of 3rd International Symposium on Block and Sublevel Caving, 5-6 June, Santiago, Chile, 2014, p. 337-347.