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Research Paper

Analysis of Factors Affecting In-pit Dumping in Metallic Open Pit Mines

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Abstract: In today's world, industries and societal advancements have compelled the mining sector to extract greater quantities of minerals. Open-pit mining, known for its high productivity, generates substantial amounts of waste. It is essential to dump this waste, but the dumping of mine wastes can lead to various issues, including environmental degradation, future space constraints, and increased transportation costs. A potential solution is the in-pit dumping approach; however, this method, which has been effectively employed in surface mines like coal, requires careful consideration of whether it can be adapted to open-pit operations. The aim of this study is to explore the feasibility of an in-pit dumping approach in open-pit metal mines and to evaluate the influencing factors. We begin by identifying the key elements that affect in-pit dumping, followed by a geometric analysis of several of these factors, including the length, slope, and thickness of the deposit, as well as overburden volume and the ratio of length to thickness. This analysis is conducted in two dimensions. After assessing the sensitivity of these influential factors, we determine that the most critical is the ratio of horizontal extent to vertical extent — or the ratio of length to thickness of the deposit. Our findings suggest that the optimal ratio lies between 6 and 7. This indicates that maintaining the ratio within this range allows for maximum in-pit dumping of waste in open pit mines.

Keywords: Metal deposit, Open pit mines, Waste dumping, Geometric factors, Sensitivity analysis.

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INTRODUCTION

This paper investigates the feasibility of the in-pit dumping approach (IPD) in open-pit mining, particularly focussing on metal mines. As surface mineral reserves dwindle, it is vital to explore methods that enhance net present value and reduce operational costs. The main issue addressed is the environmental impacts and logistical challenges associated with traditional external waste dumping. Existing literature emphasizes the significant environmental risks linked to external waste dumping management, highlighting the inefficiencies and costs involved in land rehabilitation. Previous studies have shown that in-pit dumping can alleviate these issues while improving waste management efficiency. However, most research has focused on layered deposits, particularly coal, leaving a gap in insights regarding non-layered resources. This research utilizes a geometric analysis to evaluate conditions favorable for implementing IPD in open-pit mining. Key factors, such as the horizontal extent and overburden thickness, are examined to assess their influence on the viability of in-pit dumping. A base model is developed to quantify these effects, along with sensitivity analysis to identify the most impactful variables. The findings indicate that the in-pit dumping approach in open pit mines can be applicable when specific conditions are met, notably a horizontal extent-to-thickness ratio of the roe body between 6 and 7. This approach demonstrates the potential for substantial cost savings and improved operational efficiency, offering a viable alternative to traditional waste management methods. The study contributes important insights for optimizing waste dumping strategies in open-pit metal mines.

METHODS

This study conducts a geometric analysis to evaluate the parameters affecting in-pit dumping and their sensitivity. A hypothetical two-dimensional model of a mine was developed to analyze various factors impacting in-pit dumping. The findings highlight several geometric characteristics that significantly influence the feasibility of this method: Deposit Shape, Deposit Thickness, Deposit Slope, Horizontal Extent and Spread, Overburden, and Topography. Quantitative analysis of these factors is essential. In this research, one parameter was systematically varied while keeping four others constant to examine its effect on in-pit dumping and to graph the results. Subsequently, the influences of these factors were compared to analyze their sensitivity.

The geometric analysis in this study is based on a foundational model. A hypothetical rectangular deposit, measuring 80 meters in length and 20 meters in thickness, is considered at a depth of 30 meters from the surface, with a slope of zero degrees. It is assumed that the entire deposit is extractable, and the surface is treated as entirely flat. This deposit is extracted using a two-dimensional pit with a stable slope of 45 degrees. Figure 1 illustrates the initial conditions of the hypothetical mine. The swell factor is estimated to be between 30% and 40%, with an average of 35% used for calculations.

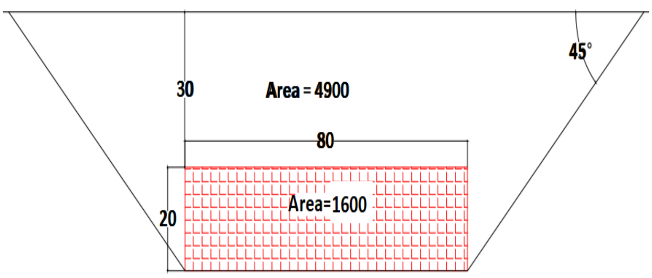

Figure 1. Initial condition of hypothetical mine for geometric analysis

FINDINGS AND ARGUMENT

According to Figure 2, the most sensitive factor influencing in-pit dumping across the entire pit is the horizontal extent of the deposit, as demonstrated by the steepest slope in the sensitivity analysis chart. The length-to-thickness ratio indicates the horizontal to vertical extent of the deposit; thus, assessing the horizontal extent in relation to its vertical counterpart is crucial before evaluating other influential factors. The second most sensitive parameter is the deposit thickness, which significantly impacts the percentage of IPD. An optimal thickness exists, maximizing the in-pit dumping percentage while accommodating the maximum amount of waste. This optimal point corresponds to a length-to-thickness ratio between 6 and 7. The deposit slope and the amount of overburden are the next two most sensitive factors. Generally, increases in these parameters lead to a decrease in the percentage of in-pit dumping. While slope affects IPD in a nearly linear relationship, the overburden's impact is non-linear; initially, increases in overburden substantially reduce the IPD percentage, but beyond a certain point, this effect may neutralize. Lastly, deposit length demonstrates the least sensitivity to IPD. This parameter positively correlates with the IPD percentage—an increase in length leads to an increase in IPD. However, similar to overburden, this relationship is not linear; initially, longer deposits boost the percentage, but after a certain point, the rate of increase diminishes significantly.

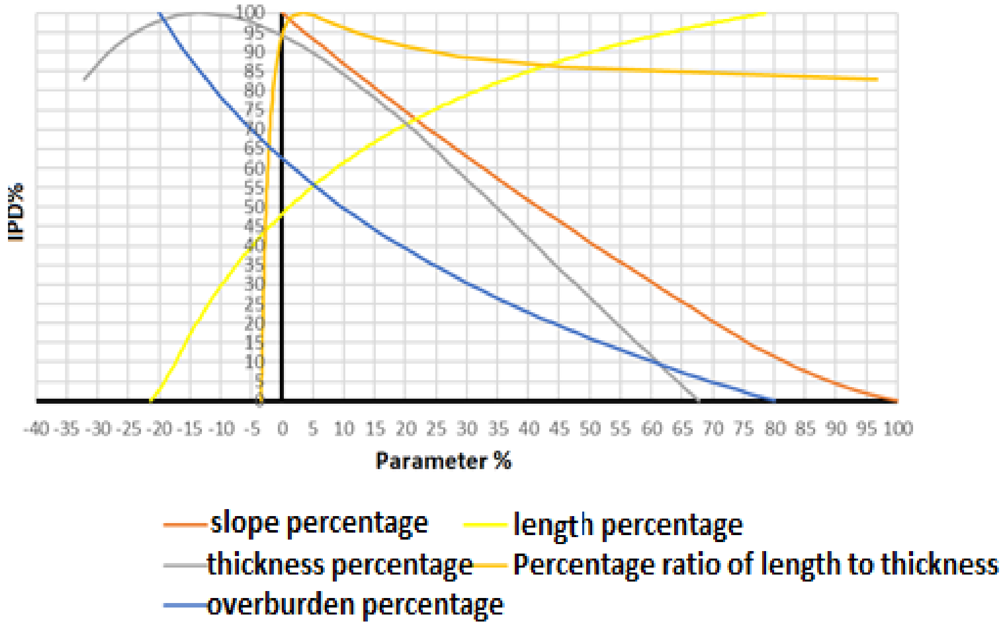

Figure 2. Sensitivity analysis of ipd percentage to different parameters

CONCLUSIONS

The goal of this study is to examine in-pit dumping in metallic open-pit mines and analyze the factors influencing it. To achieve this, the study first identifies the key conditions under which an in-pit dumping approach can be implemented, pinpointing the most significant influencing factors. Additionally, it seeks to estimate the potential volume of in-pit dumping under optimal conditions. To assess the impact of various parameters—such as deposit slope, length, thickness, overburden, and length-to-thickness ratio—a two-dimensional geometric analysis was conducted using AutoCAD. Results indicate that the most critical factor is the horizontal-to-vertical extent ratio, with an optimal ratio between 6 and 7, allowing for maximum waste to be dumped within the pit. Other factors like deposit slope and overburden also play significant roles. However, this geometric analysis has limitations:

1. It is two-dimensional, which may yield different results for three-dimensional deposits.
2. It is based on a model with fixed initial conditions, meaning variations in these conditions could produce different results.

While the findings are applicable under ideal conditions as per the base model, they require further detailed analysis for real deposits. Nonetheless, this study provides a solid foundation for exploring the nuances of the in-pit dumping approach in open-pit mining, helping to estimate the overall potential for in-pit dumping within the pit.

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