Semi-Automatic Generation of Ramps in Open Pit Mining Using Mathematical Programming

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ABSTRACT

The design of ramps in open pit mines is a key step in the mine planning process in which the economic envelopes obtained by optimization techniques and algorithms are transformed into operational volumes (phases) that are suitable for extraction. Despite the existence of tools that aid in the design of ramps, this process remains very complex and time consuming. This implicates few opportunities to explore different arrangements and, thus the quality of the resulting design depends on the engineer's expertise and availability of time.

In this paper, a mathematical model is presented which allows a semi-automatic generation of the ramp design from the economic envelope of a pushback at a block level. The inputs for this model are a valuated block model and design constraints, such as, ramp width, inter-ramp slope angle, ramp slope and others, generating a block path that allows to achieve the maximum value of the resulting envelope.

Different experiments were undertaken by modifying the input parameters, for instance, the starting block, rotation (clockwise and counter clockwise) and limits of the search domain of the ramp, with the purpose of generating a guide to assist in the design of the ramps achieving maximum profit. Using this guide, the final pit design was generated allowing a comparison with the current state-of-art in ramp design for open pits.

The results indicate that the methodology assisted by the mathematical model obtains very similar values in relation to the current state of the art, for the study case, however, it is possible to conclude that this tool provides greater robustness to the planning process; allowing to analyze different design scenarios in a limited period, ensuring an optimum economic design.

INTRODUCTION

Within long-term mining planning, the operational design of phases consists of incorporating access to each phase and the connection between them, to obtain the largest possible part of available reserves, subject to the trade-off between extracting more ore and the associated waste, or less waste and associated ore. This certainly has an impact on the economy of the mining project.

Accesses to extract and transport the material from inside the pit are made by ramps which allow the movement of the mining equipment. Currently, it is one of the subjects of which little is written in the mining literature; because planners do not have a definitive methodology for design (Hustrulid, Kuchta & Martin, 2013). However, a good design of the ramp geometry will be one that delivers the greatest economic benefit (contained in pit design reserves with ramp), fulfilling all geometric specifications imposed by geotechnics (Thompson R., 2011).

In truck-based transport systems, the network of transportation roads in mines is a critical and vital component of the production process, since truck costs can account for up to 50% of the total operating costs incurred by an open pit mine (Thompson R., 2011, Atkinson, 1992), and any savings generated by better design and management of ramps directly benefits the mining company, as a reduction of cost per metric ton of material transported.

Under the current state of art, ramp design presents difficulties. First, the task requires a lot of work, skills and information, so, the opportunities to test different scenarios, or check the robustness of the solutions are limited. Secondly, even if the obtained solution is the best possible, much time is required to create a design, which means that the task is very expensive. Finally, the fact that design is generally a manual process, it can be supported by computer-aided design (CAD) software, and that the operating phases do not necessarily coincide with the original pushbacks, since the algorithms that generate them do not consider elements of design such as operative spaces and ramps, there is no guarantee that the resulting benefits will be the best.

Considering the mentioned improvement opportunities, will there be the possibility of introducing a mathematical tool that maximizes the value of the mining project, through a guide in the design of ramps? In this paper, we seek to take a first step towards generation and implementation of a tool of this type.

CURRENT STATE OF ART IN THE RAMP GEOMETRIC DESIGN

The geometric design, is responsible for the layout and alignment of the ramps, both horizontally and vertically (Thompson & Visser, 2006). There are many questions that must be answered at the moment of locating the ramps, among the main ones: Where will the ramp surface go? Should there be more than one means of access? Should the ramps be external or internal to the pit? Should they be temporary or semi-permanently? Should the ramp spiral around the pit? Does it have switchbacks anywhere? How many roads must the ramp have? What should be the ramp slope? What should be the direction of traffic flow? and is the trolley assist a viable consideration for trucks?