Metal Mining

Block/panel caving pressing final open pit limit

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ABSTRACT

During the past fifteen years, mines utilizing the block caving method have improved performance and systematically reduced total mining costs.

This paper describes improvements in mine design, mine planning, and mine management, including methods enabling the Chilean and international mining industry to ensure cost savings and productivity growth while using the block caving method. These improvements have encouraged the re-evaluation of underground operations at operating and closed open pits, and challenge surface mining applications as the only low-cost mining method. This paper describes a strategy to estimate the optimum open pit to underground transition time during the life of a mine.

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Introduction

During the last fifteen years, block caving mines have experienced huge changes in designs, planning and administration. These changes have permitted operators to drastically reduce costs, improve equipment productivity, and improve overall business performance. As a consequence of this situation, the block/panel caving mining system is challenging actual open pit operations to maximize the net present value (NPV).

Block/Panel Caving

There are large-scale operations in Chile where the main mining method is block/panel caving. There are three mines in operation, some of them dating back to the earliest years of the past century.

These operations have a production rate ranging from 35 000 t/d to 97 000 t/d. El Salvador mine is the smallest mine and El Teniente, the largest. Andina mine, a medium-size block caving operation, has a production rate of 46 000 t/d. All of them are operated by Codelco Chile, a state-owned copper company. El Teniente is expanding to achieve 126 000 t/d for the next two years.

Mine Planning

During the early 1990s, major changes occurred in the planning process, such as computer-assisted applications, ore resources management, and geotechnical and metallurgical advances. This planning process improvement has permitted mining sequence analysis, the introduction of complex algorithms for dilution simulation, and production control. The inclusion of financial tools, such as NPV analysis into the mine planning process was, a major change.

The opportunity cost is one of the most radical changes ever made in mine planning, where the goal is to maximize the NPV instead of to maximize orebody recovery. This strategy allows us to evaluate and to define if a column in a draw point has to be extracted up to the critical ore grade or to a higher value, with less orebody recovery, looking to not delay more profitable orebody recovery ahead in the mining sequence.

The historical results have demonstrated there is equilibrium between maximizing NPV and orebody recovery. These have to be managed carefully because of the great uncertainty in some of the main input parameters as the metal price forecasts.

There is no doubt that considering the opportunity cost in the mine planning process will improve the economic performance of the enterprise.

Mine Design and Mechanization

Mine design improvements have also contributed to cut costs and improve productivity and effectiveness. Figure 1 shows a general diagram of the block caving mining method using LHD.

Before the mines reached the primary ore (competent rock), there were several advances in drilling and blasting, reducing the amount of drilling and the explosive consumption to produce caving in 3/5 of the historical designs, coming from a full ring pattern to a half-ring pattern.

Today, the primary ore is in more competent rock and has to be extracted from draw points with a significant increase in hang-up occurrences, time, and resources for secondary blasting.

Codelco is very advanced on testing some special blasting of the non-caved rock, looking to precondition the rock mass and reduce boulders and hang-up frequency into draw points.

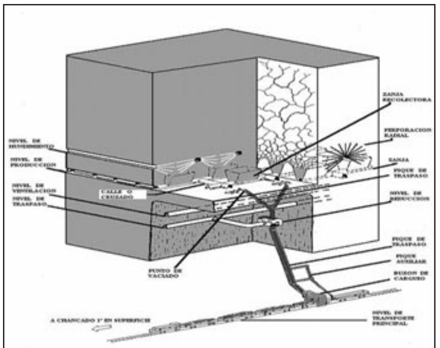

Fig. 1. Block caving mining method.

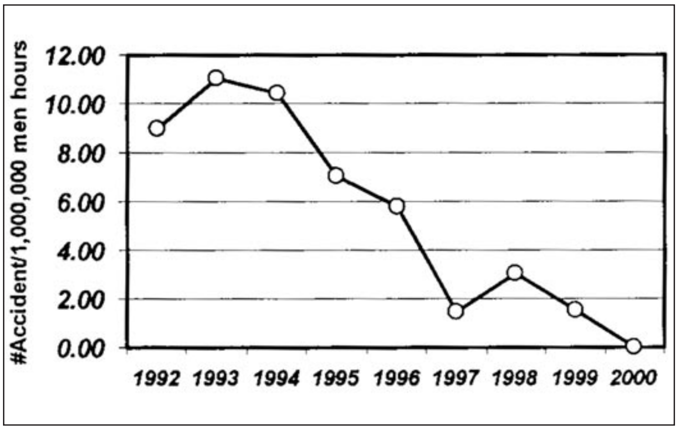

Fig. 2. Accidents rate El Salvador mine.

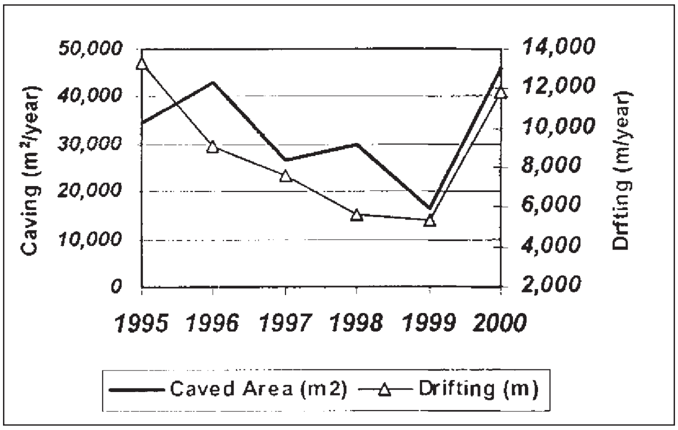

Fig. 3. Caving and drifting requirements, El Salvador mine.

Other design improvements are:

- remote control operation of hydraulic rock hammers (rock breakers);
- replacement rock hammers with jaw crushers as reduction equipment in primary rock areas;
- replacement of rigid ground support systems by active ground support; and
- increased size of LHD equipment from 5 cu. yd up to 13 cu. yd.

Environmental Health and Safety

Other important factors related to operations have been constant improvements on health and safety conditions. Figure 2 shows the evolution of the lost time accident rate of one of these block caving mines.

A strong program of controlling the rate of accidents started during the early 1990s in all of these mines, significantly reducing rates of accidents and production disruptions. These programs are based on operational procedures for all specific jobs. These procedures are produced by workers and supervisors looking to identify risks and to mitigate those same risks.

Environmental aspects of occupational health were included in the mine design and on the equipment specifications, such as the introduction of LHD with pressurized cabins.

The continuous reduction of personnel has helped to improve the effectiveness of all permanent training systems and supervision tasks.

Outsourcing Cost

Another goal in the improvement of mine management was the transfer of most of the fixed costs to variable costs. One of the most important actions that these mines implemented was a reduction of preparation and construction resources. There was a conviction that the preparation activities were strategic operations during the early 1990s. The mines had a large amount of people and equipment directly associated with these activities (miners, jumbos operators, concrete mixer trucks, etc.).

It has been determined that the demand of caving area and preparation operations are usually variable, as is shown in Figure 3. It is possible to see the El Salvador mine caving area and drifting demand statistics between 1995 and 2000. This demand can be properly planned and depends on the economic column heights and the drawing rate. These variable requirements suggest that it is appropriate to look for outsourcing in these areas.

This strategy permitted the definition of highly variable annual quantities for preparation and caving activities, reducing the requirement of miners, equipment, and maintenance personnel.

Nowadays, these activities represent between 45% to 65% of the total mining cost in a block caving operation. Before the outsourcing strategy was implemented, caving and drifting operations represented between 60% and 75% of the total mine cost. Today, most of the Chilean block caving mines are carrying out only production activities with their own personnel and a small staff to tend to emergencies in mining infrastructure maintenance.

Figure 4 shows the trend of the total mining cost for block caving operations in Chile. The main reason for this range is because of the local conditions of each mine and the total daily throughput.

Impact in the Final Pit Definition

The performance reached in this underground method allowed the authors to review final limits already defined for some of the actual open pit operations, as well as to consider this effect in new projects nowadays under study.

It is not simple to define when the best moment is to change the mining method from open pit to underground. The main issues here are the risks involved in this decision, how to change or to adapt the infrastructure, skills and knowledge, and the organization's ability to accept change.

The authors could not yet find an algorithm to simultaneously manage and generate the proper mining schedule generation for both methods simultaneously (underground and open pit) without considering the economic evaluation. Metalica took part in two studies analyzing this; one case is Chuquicamata mine and the other is the MM Project, both from Codelco.

First Step

The final pit, as defined by normal industry practice (i.e., the last push back is what maximizes the net present value of the open pit mine planning), was designed as an underground primary and general project using the block caving method (shown graphically in Figure 5). This primary project supported a NPV at the end of the open pit life called NPV_U.

Second Step

After this base definition, the authors successively analyzed the expansions from the open pit , adjusting all mining open pit design, scheduling, and cash flow estimations.

Simultaneously, for each scenario, the resources not considered by the new geometry

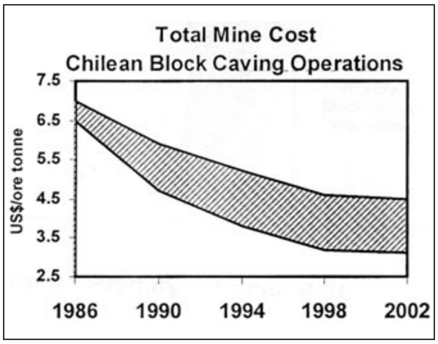

Fig. 4. Trend of total mining cost, Chilean block caving.

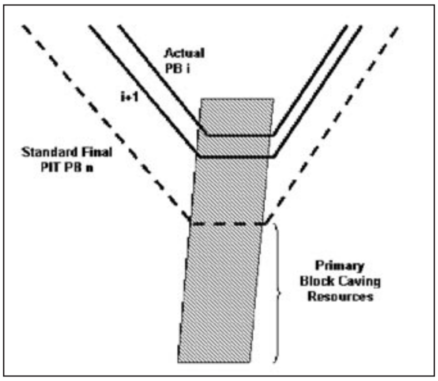

Figure 5. Primary configuration.

of the pit were added to the underground design, adjusting sequence, mining plan, cash flow estimation schedule, etc.

Results

Each configuration produces a new NPV giving an economic sequence of the global business that helps identify the scenario of maximum NPV. Figure 6 shows a possible NPV sequence that could be obtained from this kind of analysis. There is a strong relation between the results of the analysis and the robustness of the underground project.

The benefit of each push back removed from the design of open pit must be compensated for with at least a greater benefit

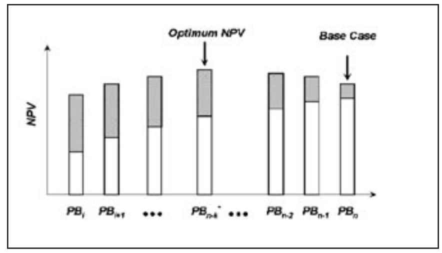

Fig. 6. NPV by scenario.

obtained to advance the underground project (effect of the discount rate). In addition, there is an extra benefit obtained from new ore reserves left by the design of the new pit. In both cases, Chuquicamata mine and the MM Project, a significant change of the base configuration could be demonstrated, with an increase in the NPV about 12% of the original value.

Conclusion

The main conclusions obtained from these studies are:

- Block caving appears to be a great competitor for deep ore resources for actual open pits.
- It is necessary to consider the value of the future ore resources when looking for an optimal definition of a final pit.
- Metalica could not find a proper algorithm to manage this optimal search.
- There is a wide research field for software providers because many large mines are looking for analytical support for these kinds of decisions.
- As well, mining consulting enterprises need to improve their procedures and performance.

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