MINERAL MINING TECHNOLOGY

Transition from Open-Pit to Underground in the Case of Chah-Gaz Iron Ore Combined Mining

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Abstract—Geological and economic modeling of an ore body and also optimization of the depth at which transition is made from open-pit to underground mining is an important part of the mining design process in large and massive deposits. In this paper, a geological block model of Chah-Gaz iron ore deposit located in Iran was first created based on iron ore cut-off grade. Then with considering the economic parameters in the geological block model an economic model was derived. The economic block model of the deposit was used to determine the transition from open-pit to underground mining. The transition depth determination process was mathematically modelled for the case study. The objective function was chosen to be the maximization of the total profits earned from the combination of both open-pit and underground mining of the deposit. Chah-Gaz transition problem was finally solved by developing MATLAB optimization based code. The results obtained indicate a transition depth of 450 m.

Keywords: Mathematical programming, transition, open-pit to underground, combined mining, Chah-Gaz.

INTRODUCTION

Mineral deposits may be so near surface that their exploitation by surface methods can easily be accomplished. There are on the other hand deposits whose depth from the surface would only allow them to be won by underground methods. Apart from these clear-cut situations, there are also some deposits that start at surface or near surface and continue to great depths. In the case of such deposits, using a combination of both surface and underground methods could result in a higher net profit than only one. If such decision is taken, the design engineer must then determine a depth at which the mining method changes from surface to underground. The value of this depth depends upon many factors and sub-factors. One of these is the underground method adopted which in the case of this research has been decided to be block caving.

Open-pit, underground or a combination of open-pit and underground methods will therefore be selected on the basis of, amongst other things, the ore deposit geometry (dimensions, shape and depth), rock characteristics and conditions, productivity, capacities of machineries, capital requirements, operating costs, investments, amortization, depreciation, ore recovery, safety, environmental aspects etc. [1].

It is generally expected that using open-pit methods are advantageous to underground methods since the former are expect to have a higher production and productivity, mechaniziability, ore recovery, grade control, safety records and lower ore loss and dilution, investment and costs. Underground mining has, however, gained popularity in recent decades due to the fact that they are less detrimental to the natural environmental in terms of leaving a permanent footprint in comparison with an open-pit of similar capacity [1].

1 The article is published in the original.
Figure 1 shows a typical open-pit mine with its benches, machines and ramp. In open-pit mining, before beginning the ore extraction overburden (waste rocks) must be removed. Ramps and haulage roads play the major role in transmission of the extracted ore from open-pit bottom to the surface. Extraction arises from benches [2]. The major factors influencing an open-pit layout are: deposit shape and depth, slope angle limitations, grade variations and cut-off grade limits and equipment characteristics.

As for underground mining methods, these are divided into three categories [3]:

1. Naturally supporting methods such as room-and-pillar and sublevel stoping.
2. Artificially supporting methods such as shrinkage and cut-and-fill mining.
3. Caving methods that can be subdivided into sublevel caving and block caving.

Among these categories, caving methods and in particular block caving can result in lowest cost per ton of the ore extracted. The method can only be applied to large and massive deposits that are often suitable candidates for the application of combined open-pit and underground methods.

Figure 2 shows general features of an underground mine that uses block caving. The method can be applied to ore deposits of much lower grade as long as they are large or massive with appropriate fracture pattern [2]. After undercutting, the ore body caves naturally due to the force created by the weight of ore and surrounding strata. Drawing of the caved ore below the ore column continues until the entire ore above the undercut breaks into suitable sizes for handling. Since there is no control over fragmentation of the extracted ore, secondary blasting, however, is an inseparable part of the method. The main disadvantages of the method are dilution and ore loss together with their measurement and control. Both these are inherent to the method but difficulties in their control may lead to the situation where the method becomes unacceptably expensive.