STRATEGIC PRODUCTION PLANNING OF IRON ORE IN GHORABI AREA, BAHARIYA OASIS

By

Mohamed Samir Saeed Sholqamy

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
In
Mining Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Summary:

Ghorabi Deposit is one of the four promising iron ore reserves located within the Bahariya Oasis among El Gedida, Nasser and El Harra. The iron ores of Bahariya oasis generally is considered of strategic importance as the steel industry is a major contributor to the national economy of every developed country. Previous studies had confirmed the existence of iron ore upgrading problem related to decreasing the concentration of detrimental elements such as manganese and chlorine. Their concentrations in some regions reach up to 15% and 8% respectively, which is very high according to the blast furnace required specifications and also cannot be processed by mineral dressing techniques economic wise.

The main aim and objective of this thesis is to present some possible production planning and scheduling scenarios that can be used in order to exploit the mineralization with efficiency. This is done by firstly studying the ore statistically and breaking it down into different domains of mineralization. Then, a geostatistical study is carried out for each of these domains to study the mineralization spatially and to produce a good estimate for its contents. This is followed by the determination of the final open pit limit design using the Lerchs and Grossman algorithm. The final step is to achieve an annual production plan and a schedule using the Milawa algorithm using the annual production rate as the main constraint.

Four scenarios have been studied, two of them have a production rate of 1.5 mil.tons/yr with a mine life of 37 years, and the other two have a production rate of 3 mil.tons/yr with a mine life of 19 years. the first one of each of the two cases aims at maximizing the net present value of the ore, while the other two is with the aim of balancing the produced ore grades as possibly as could be done reaching a uniform mill feed. Also, the extraction block sequence for each year of the mine life is presented.

Disclaimer

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university of institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the references section

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Abstract

Ghorabi iron ore area is one of the four promising iron ore reserves located within the Bahariya Oasis district among El Gedida, Nasser and El Harra. The iron ores of Bahariya oasis generally are considered of strategic importance for its major contribution to the national economy of every developed country through the steel industry. Previous studies had confirmed the existence of iron ore upgrading problem related to decreasing the concentration of detrimental elements such as manganese and chlorine. Their concentrations in some regions reach up to 15% and 8% respectively, which is very high according to the blast furnace required specifications and also cannot be processed by mineral dressing techniques economic wise.

The main aim and objective of this thesis is to present some possible production planning and scheduling scenarios that can be used in order to exploit the mineralization with efficiency. This is done by firstly studying the ore statistically and breaking it down into different domains of mineralization. Then, a geostatistical study is carried out for each of these domains to study the mineralization spatially and to produce a good estimate for its contents. This is followed by the determination of the final open pit limit design using the Lerchs and Grossman algorithm. The final step is to achieve an annual production plan and a schedule applying the Milawa algorithm using the annual production rate as the main constraint.

Two case studies have been investigated based on the ore annual production. The first case study simulates the current annual production rate of 1.5 million tons/yr with a mine life of 37 years according to the design capacity of the blast furnace. The second case study simulate projected extension strategic plan of doubling the ore production rate to 3 million tons/yr within a mine life of 19 years.

For each of the two case studies, two scenarios have been investigated. The first scenario simulates maximization of the net present value (NPV) of the ore, while the second scenario aims to balance the produced ore grades as possibly as could be done to reach a uniform mill feed. The obtained results states that it is possible to produce iron ore tonnage that satisfies the specifications of the blast furnace for a long portion time that is more than half the mine life.

Chapter 1 : Introduction

1.1. Overview

Ghorabi deposit is one of the four promising iron ore reserves located within the Bahariya Oasis among El Gedida, Nasser and El Harra. These reserves had been evaluated in 1967 by the Geological Survey Authority. Ghorabi and Nasser areas had been reassessed again in 1975 by both of the Iron & Steel Complex and the Egyptian Geological Survey and Mining Authority. Great attention is being paid to these reserves as it is planned to exploit them to increase the total amount of produced iron ore to satisfy the industrial needs of the Iron & Steel Complex.

Open cast mining was decided to be the method for the exploitation as 40% of the ore body has an exposed surface and the stripping ratio was found to be 0.1 m^3/ton. Open cast mining method is a special case of the open pit mining where the ore body to be extracted is not so deep. It is always known that open bit mining is more attractive, investment wise, than the underground methods due to: lower production costs, high productivity, higher safety, etc. Since this thesis will consider only the production problems of Ghorabi iron ore, the terminology of mine design and production planning will be only referring to the open cast method.

The primary objective of this thesis is to develop a schedule telling when and where mining operations should take place over the different time periods during the mine life. The Net Present Value (NPV) analysis is most widely used to evaluate mining venture as the fundamental mission of any mining company is to maximize the NPV produced by its mining projects. Therefore, generally, the design is optimal when the maximum NPV is realized.

In reality, it's too difficult to reach the true optimum mine plan due to the long production life, great uncertainty of the ore reserve estimations and other uncontrollable risks, such as: geological risks, engineering risks, economic risks and political risks. In spite of these difficulties, the best possible mine plan must be worked out at great efforts, since any mining company cannot afford the cost of mistakes in the planning process. Therefore, the development of optimal, or near so, mine plan is very complex procedure due to the very large number of variables and constrains involved.

Nowadays, the mine pit limit design can be accomplished completely by computers using today's techniques and computing facilities. However, mine production planning and scheduling is still carried out partially by computers and partially by hand. A typical open pit mine design and planning usually involves these main tasks: geological survey, rock mechanics study, mineralization modelling, ultimate pit limit design, long range planning and short range planning.

1.2. Statement of Mineralization Modelling Problem

The mineralization modelling is the process of transforming the known features of a real deposit into a mathematical model that can be manipulated by computers. The commonly used technique is to transform the ore body into smaller fixed units defined as blocks and the model is called a Block Model. This Model is a 3-D fixed model that

can store different type of data, usually geological and chemical composition. For the purpose of this thesis, the continuity, isotropy of the ore, and the dimensions of blocks have been defined based on the obtained geostatistical parameters,. Also, the geometrical considerations such as, machinery dimensions and mining width can play a significant role in determining the height of the block, which usually is equivalent to the extraction bench height. Chemical composition or the grades defining each block is usually estimated by the Ordinary Kriging method in order to apply further analysis, economic in particular.

1.3. Statement of Ultimate Pit Limit Problem

The ultimate pit limit problem can be defined as a combination of mining economics and mining inventory under geological and geometric constrains to reach the size and shape of an open pit mine at the end of its life. The main objective is to maximize the difference between the revenue obtained from the extracted ore and the total mining cost while satisfying pit slope stability. After the final pit is determined all of the subsequent mine planning works are performed within that pit limit [1].

The ultimate pit limit determination is considered the foundation of all the planning and scheduling operations. Therefore, establishing the correct ultimate pit limit is of utmost importance. The ultimate pit plan plays a very important role in the evaluation of the economic potential and the initial feasibility study of the studied mineral deposit.

Many variables are considered while studying the ultimate pit limit design. Kim (1979) lists these main variables after excluding the operational considerations: grade and its spatial location, recoverability, market price, mining rate, milling rate, mining sequence, pit wall slope, mining cost, processing and refining costs. The variables are highly interrelated. For instance, mining cost influence the total minable ore reserve as the higher the cost the smaller the reserve and vice versa. Also, the total reserve in turn influences the mining rate, capital investment, and mining sequences, which would alter the mining costs, leading to a circular process of evaluation as shown in figure (1.2). The deal here is to fix some values at some predictions or assumptions.

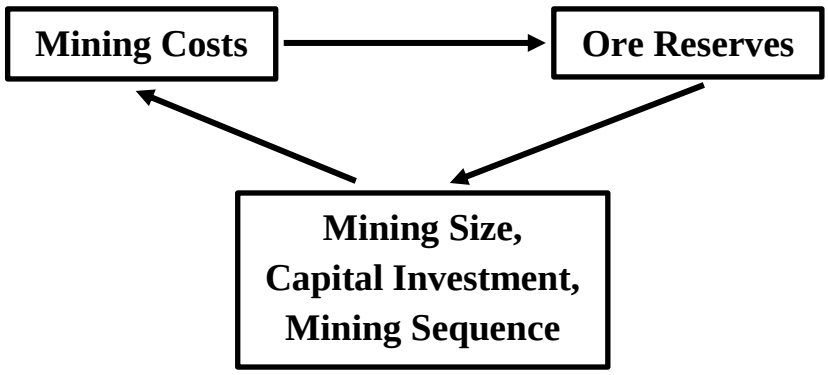

Figure 1.1: Cyclic Nature of Mine Evaluation Process [1].

1.4. Statement of Planning and Scheduling Problem

Long range production planning is defined as developing a multi-period mining sequence which will deplete the mineable ore reserves from the initial condition of the deposit to the ultimate pit limit. The time span could range from one year to several years.

The mining sequence development aims to maximize the NPV of the cash flow throughout the mine life while maintaining a reasonable degree of operational continuity. This continuity (sequencing) could be represented as meeting grade-tonnage requirements and haulage roads accessibility, etc. The long range planning provides the conceptual framework for the mining activities and deals with future strategies. It has a great influence on the profitability of the mining venture. The NPV of each mining operation can be often improved by starting with a higher cutoff grade in the early periods to achieve a higher rate of return then tapering to a lower cutoff grade (Lane, 1964; Blackwell, 1970; Marek and Welheer, 1985).

The pushback mine sequence is a heuristic optimization approach which has been widely accepted by the mining industry as the most practical method for long range mine planning and sequencing. The main steps in this approach is to determine the pushbacks or phases and the development of the mining sequence among these pushbacks.

A series of nested pits would be obtained by repeatedly applying the pit limit design algorithm by gradually decreasing the product prices while keeping the production costs constant. The mining width is the controlling parameter in determining the different possible scenarios of pushback determination. The pit is considered a pushback if the horizontal distance between it and the following pit exceeds the mining width. These different scenarios is then studied and a particular mining sequence could be worked out based on the highest NPV.

1.5. Aim and Objective

- Re-evaluation of Ghorabi area by applying the computerized techniques of Geostatistics, Kriging, Orebody modelling and Simulation.
- Determination of the final pit limit design by the Lerchs and Grossman algorithm.
- Studying different production planning scenarios and different possible annual mining scheduling and sequencing of the ore.