Multi-objective Optimization of Grades Based on Soft Computing

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Abstract. Economic benefit and resource utilization rate should be considered when optimizing the cut-off grade and grade of crude ore in production management of metal mine. This paper introduces soft computing to the field of mine, to determine the combination of grades in the condition of multiple objectives, and its basic idea is that, ANN is used to model the nonlinear function from the relative variables to metal recovery of milling and total cost, fuzzy comprehensive evaluation integrates multiple objection, GA searches for the optimal grades combination, these three techniques not only function independently but also effectively integrate together, collectively display the function of modeling, reasoning and optimization. Take Daye Iron mine as an example, and it indicated the validity of proposed method, from January to November in 2007, the optimal cut-off grade and grade of crude ore are 16.53% and 43.14%, respectively, and contrasted to the present scheme, lower cut-off grade and higher grade of crude ore can produce more amount of the concentrate ore, get more profit, and enhance higher utilization rate of resource.

Keywords: Multi-objective optimization, Soft computing technique, Cut-off grade, Grade of crude ore.

1 Introduction

In production and management of mining enterprises, we are not only in the pursuit of economic interests, but also take into account of the resource recovery and other relative objectives. Cut-off grade and grade of crude ore are two key indicators in production and management of mine, the optimization is a multi-objective optimization problem. Tao Yong [1], Zhao Dexiao [2], Jiang Annan [3], etc. optimized the grades considering economic benefit with single-objective optimization. However, with the changes from extensive to intensive of mining enterprises and the shortage of resources, we should not only consider economic benefit, but also emphasize on the utilization of resources in the production practice. Li Keqing [4,5], Yuan Huaiyu [6], YU Weijian [7], Li Keqing [8] tried to work on multi-objects optimization, but the decision-making variables were not the combination of cut-off grade and grade of crude ore. Cut-off grade and grade of crude ore are two concepts related with income, cost, geological grade, loss rate and dilution rate. The mapping function between them...
are highly-complex and highly-nonlinear, and it is difficult to directly or indirectly find out the mathematics expression.

Soft Computing (SC) [9] is a novel method to create complex system, in order to deal with complex problems under the uncertain and imprecise environment, a variety of different sources of knowledge, technology and methods need to composite and collaborate for computation. Soft computing mainly contains three parts: artificial neural network (ANN) is responsible for pattern cognition and adaptive modeling by changing environment; fuzzy logic (FL) is for reasoning and decision-making of human knowledge; genetic algorithm (GA) leads the system to reach optimization. These three techniques not only function independently but also effectively integrate together, collectively display the function of modeling, reasoning and optimization. In recent years, soft computing has been successfully used in optimization, evaluation and forecast in the fields of engineering technology, economic management, and so on. In this paper, soft computing technique has been used to optimize cut-off grade and grade of crude ore with multiple objectives, to enhance the overall benefit of metal mine system.

2 Set the Objectives

The optimization of cut-off grade and grade of crude ore is based on the economic benefit and resource utilization. The objectives are net present value (NPV), resource utilization rate and total amount of concentrate, respectively. According to mining and milling production process, we set three objectives as follows:

\[
\text{MaxNPV} = \sum_{t=1}^{n} \frac{R_t - C(a_t, q_t, a_j, a_r)}{(1 + i)^t}
\]

where, \( R_t = \frac{a_t q_t (1 - \phi(a_j)) e(a_t, q_t, a_j, a_r)}{\beta} \) \( J, 0 \leq a_j \leq a_r \leq 1 \) \( (1) \)

\[
\text{MaxUTI} = \frac{\sum_{t=1}^{n} a_t q_t (1 - \phi(a_j)) e(a_t, q_t, a_j, a_r)}{\sum_{t=1}^{n} a_t q_t}
\]

where, \( 0 \leq a_j \leq a_r \leq 1 \)

\[
\text{MaxCON} = \sum_{t=1}^{n} \frac{a_t q_t (1 - \phi(a_j)) e(a_t, q_t, a_j, a_r)}{\beta}
\]

where, \( 0 \leq a_j \leq a_r \leq 1 \)

Where, \( \text{NPV} \) denotes net present value, \( R_t \) denotes revenue of the ore body in the \( t \) th month, \( a_j \) denotes geological grade in the \( t \) th month, \( a_j \) denotes cut-off grade,