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Multi-criteria decision making for collector selection in the flotation of lead–zinc sulfide ore

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ABSTRACT

The results of multi-criteria decision making (MCDM) for the selection of the optimum sulfide mineral collector and dose rate in a flotation study are presented. Laboratory scale flotation tests were performed to investigate selective flotation of galena from lead–zinc sulfide ores using several different xanthates at different dose rates. The flotation results show that the different tests result in changes lead concentrate grade, lead recoveries and selectivity against zinc. According to the selection criteria to maximize lead concentrate grades and recoveries while minimizing zinc concentrate grades as different factors, decision making and final selection of the optimum collector and dose rates are not simple since there is multiple options and outcomes to consider.

A technique for order preference by similarity to ideal solution (TOPSIS), as well-known MCDM method, has been used for ranking xanthates not only using technological, but also economical factors. The results obtained show that MCDM is a useful tool for ranking and selection of tested collectors in flotation because of the ability to evaluate all factors fixed in flotation tests. The final step is a developed mathematical model for selection of optimal collector.

1. Introduction

One of the most important and basic concept in mineral processing is metallurgical efficiency, while recovery and grade are commonly used to describe the efficiency of metallurgical processes (Fuerstenau and Han, 2011). Metallurgical efficiency, or metal balance, is dominantly used for technological evaluation of concentration process in industrial practice, but, also, in laboratory experimental tests.

In most cases, metal balances resulted from laboratory experimental tests contains numerous quantitative values related to concentrate grade and metal recovery. It seems that in the case of simple one-metal ores, final decision and conclusions about tests can be derived easily from balances because of one recoverable metal value. However, practical examples from many mineral processing plants show that single-metal ores are complex in respect to recoverable metals (Weiss, 1985). In these cases, and especially in the case of complex ores, which contain more than one recoverable metal value (and, also more non acceptable metal values), it is very difficult to make a correct decision and right choice from metal balances without a complex solution. Specially, in relation to metal recovery – concentrate grade. It is known that “there is a problem in quantitatively assessing the technical performance of a concentration process, whenever the results of two similar tests runs are compared. If both the grade and recovery are greater for one case than other is, then the choice of process is simple, but if the results of one test show a higher grade but lower recovery than the other, the choice is no longer obvious” (Wills and Napier-Munn, 2006). “The grade of concentrate is of primary importance, nevertheless, there must be a balance between the grade and recovery” (Weiss, 1985). “Mineral processing engineers are responsible for optimizing processes to yield the highest possible recovery with acceptable purity (grade)” (Fuerstenau and Han, 2011), streaming to maximize both grade and recovery, which represent a challenge (Wills and Napier-Munn, 2006). “To achieve this goal, economic assessments of all possible technological alternatives must be conducted” (Fuerstenau and Han, 2011).

Decision making in mineral processing, particularly in laboratory tests, is not a straightforward procedure. In most cases, experimental results are graphically represented using complex procedures and, therefore, the right decisions and selection of optimal alternatives are not easy and demand time. Furthermore, conclusions and successful ranking of the available alternatives made from the initial set of tests are very often the basis for decision and plans for further experiments.

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Froth flotation is a commonly used physico-chemical separation process between valuable minerals and the gangue minerals (Wills and Napier-Munn, 2006), where xanthates, as powerful general collectors for base and precious metal are used (Adkins and Pearse, 1992). Selection of collector and other chemical reagents in the flotation process is very important. For the past few decades the effective usage of reagents in the aim of maximizing metallurgical response and minimizing operating costs was and still is one of the main concerns for researchers and operators (Greet et al., 2010). Some very useful information about reagents development and applications are well documented in several publications (Adkins and Pearse, 1992; Aplan and Chander, 1988; Bulatovic, 2007; Prasad, 1992).

This paper outlines the advantages of TOPSIS method based on fuzzy sets (fuzzy TOPSIS) in multi-criteria decision making (MCDM) for ranking and selection of the optimal collector, as reagent in the flotation process, on the basis of several criteria at the same time. The aim was to select the best xanthate from the set of available xanthates, according to the lead concentrate grade and recovery, as well as the cost of xanthate.

MCDM is a powerful tool used to select one alternative, among the set of the available multiple alternatives and more than one factor that affect the decision, fulfilling the established goals in the most effective way. "One of the principal aims of multi-criteria decision analysis approaches is to help decision makers organize and synthesize such information in a way which leads them to feel comfortable and confident about making decision, minimizing the potential for post-decision regret by being satisfied that all criteria or factors have properly been taken into account" (Belton and Stewart, 2002).

TOPSIS method was largely studied in the field of the operational research. There are many applications of fuzzy TOPSIS in the literature. Chen (2000) extended the TOPSIS to the fuzzy environment and gave numerical example of system analysis engineer selection for a software company. Chu (2002) presented a fuzzy TOPSIS model under group decisions for solving the facility location selection problem. Yang and Hung (2007) proposed to use TOPSIS and fuzzy TOPSIS methods for plant layout design problem.

In mineral processing studies, TOPSIS method was mostly used for mineral processing plant location selection (Safari et al., 2012, 2010), but not sufficiently for evaluating and selecting the optimal alternatives, or providing the final conclusion and decisions, resulting from different mineral processing methods. Hence, no reference related to collectors or some other reagents in flotation process was found. The only example of applying MCDM for resolving similar problem is related to selection of the best coagulants and its concentration in the physico-chemical wastewater treatment from the jar-tests results (Aragonés-Beltrán et al., 2009; Tzafati et al., 2011).

2. Problem description and definition

This example is related to typical sulfide lead–zinc ore in Serbia. Study is based on the primary data from the laboratory flotation tests of lead–zinc sulfide ore sample under varying process conditions.

The primary metallic minerals in the ore are galena, sphalerite and pyrite, while the gangue minerals are mainly calcite, quartz and dolomite. Galena and sphalerite dominate in the form of coarse-grained aggregates with average mill feed assays of 2.77% Pb and 2.53% Zn. The selective flotation of sulfide lead–zinc ore is typical industrial practice of lead–zinc ore preparation. The separate, selective lead and zinc flotation circuit consists of rougher and scavenger flotation and three stage cleaning circuit of the lead and zinc rougher concentrates, respectively. In the flotation circuit the conventional collectors, such as xanthates are used. Applied technological flowsheet in flotation plant and reagents regime usually provide the satisfactory quality of lead and zinc concentrate and recovery acceptable by the metallurgy. Also, the mineralogical composition, as well as the structural and textural properties of the ore were such that the presence of mineral carriers of deleterious components (like iron, arsen, antimony) poses no impediment to mineral flotation of lead and zinc, which justifies the applied reagents regime in the flotation process.

During one period of the flotation plant operation, a decrease of the overall metal recovery (lead, zinc, silver and gold) was recorded in lead and zinc concentrates. In order to resolve the problem and increase the recovery, laboratory investigation was performed.

In the first phase, the aim was to establish the grind size, a reagent regime and dosages to characterize ore response for the best metal recovery. It was concluded that significant influence on recovery and grade of lead concentrate have grind fineness, pulp pH and type and dosages of collectors.

The further step was to investigate the effects of different types of xanthates and their dosages on grade and metal recovery in lead concentrate. Laboratory tests were performed with the respect to the operational parameters and conditions in use at the flotation plant, as well as to results of preliminary flotation tests. Optimized parameters resulted from this phase of investigation included following:

- optimal grind fineness,
- pulp pH,
- number of flotation cycles and optimal time of flotation cycles,
- reagents regime (dosages of reagents and positions of their addition in the process).

The adopted technological flowsheet used for experimental investigation is presented in Fig. 1.

Experimental procedure for each flotation test was the same.

The lead–zinc sulfide ore sample was wet ground in the laboratory ball mill at 70% of solids by weight to the fineness of 65% passing 74 μm. In grinding, 150 g/t $ZnSO_4$ and 80 g/t NaCN were added for zinc bearing minerals and pyrite depression, and 1 kg/t of commercial grade lime as pH regulator and pyrite depressant.

The flotation tests were carried out in a standard Denver 2.7 L mechanical flotation cell, at 28% of solids and at 1500 rpm. At the beginning, the pH was adjusted to 8.7–9 with 0.7–0.8 kg/t of lime, followed by pulp conditioning for 6 min with 7–15 g/t of xanthate. Flotation tests were performed through rougher and scavenger flotation cycle. Total flotation time was 16 min, 8 min per each flotation cycle. Collector was added in two equal dosages of 5–10 g/t

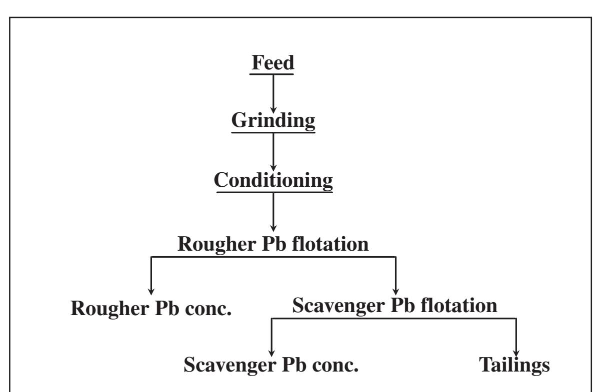

Fig. 1. Experimental flowsheet.