Parameter Screening for Collector Dosage Determination in Froth Flotation of a Sphalerite Ore

E. Tufan and B. Tufan

***Abstract*— The optimization of flotation parameters such as reagent types and dosages, pH level, flotation duration, solid ratio and particle size are significant for enhancing both the product characteristics and feasibility of the plant investment. The determination of flotation parameters of a sulphide zinc ore, sphalerite (ZnS) from vicinity of Izmir, Turkey was conducted by investigations on optimum collector dosages with already applied reagent types, pH level, solid ratio and particle size. Flotation tests performed revealed that under optimum reactive dosages, pH level, solid ratio and flotation duration, Zn grade of 34.23% with 96.45% recovery was achievable as a rougher concentrate which are between and even above acceptable limits for a bulk zinc concentrate. By conducting the scavenger and cleaner flotation stages, it is believed that the final Zn grade and recovery values would enhance significantly.**

***Keywords*—Collector, flotation, reagent, sphalerite**

I. Introduction

The limitation of sources and supplies of raw minerals and the need to treat ores of increasingly lower grades and finer particle sizes also restricts the variety of methods to be applied in mineral processing. Flotation is in fact the most common process in metallic mineral separation and is the main way for recovering such valuable metals as lead (Pb) and zinc (Zn), or copper (Cu) from ores. It is known that separation by flotation of useful minerals from gangue in an aqueous pulp happens when particles with polar, hydrophilic or wettable surfaces remain in the liquid phase, while particles with apolar hydrophobic or not wettable surfaces adhere to air bubbles. Collectors or depressing/activating reagents modify surface characteristics of minerals thus influencing affinity towards water [1].

The minerals of lead and zinc are naturally associated with each other. Three types of mineralization may be distinguished for every lead and zinc deposit: (i) Sulphide minerals, which are mainly found in the hypogene primary sulphide ore body and mineralization occurs during several successive stages, with lead and zinc being derived from this ore body. Sphalerite (ZnS) and galena (PbS) are the major sulphide minerals of zinc and lead, respectively. (ii) Nonsulphide ores, which fall into two types, hypogene or supergene weathering. The primary sulphide ore body is usually sheltered from supergene weathering by the cap of hypogene oxidized ores. Supergene oxidation ores are evidenced by the absence of sulphide minerals and their outcropping at the surface, or their near surface occurrence. (iii) Mixed sulphide–oxide ores with very complex mineralogy that are most often found in the transition, and occasionally in the oxidized, zones of deposits [2], [3].

Regarding the cost of flotation operations, the grade and mineralogical properties of the ore are the most effective factors. Depending on these properties, cost inputs and metal recoveries range from 60-95%. For the same reason, the percentage of bulk zinc concentrates produced in the world today contains 20-40% Zn and 48-60% Zn as final concentrate after cleaning stages [4]. Therefore, the optimization of flotation parameters such as reagent dosages, pH level and particle size are significant for enhancing both the product characteristics and feasibility of the plant investment. In this study, the collector dosage adjustment for the froth flotation of a sphalerite ore taken from a recently closed flotation plant near Izmir, Turkey has been accomplished. Dosages of collectors and their mixtures were experimented to achieve the highest Zn grade and recovery while the pH level, flotation duration, solid ratio and particle size remained constant. The types and dosages of other reagents such as activators, depressants and frothers were investigated and determined in early stages of the study in comparison with already applied flotation parameters in the processing plant.

II. Material and Method

The sphalerite ore (ZnS) samples were gathered from the crushed ore bin of a recently closed flotation plant near Izmir, Turkey. The run of mine ore to be fed to the plant is supplied by underground production. The host rock is mainly quartz (SiO_2). The ore coming from underground is usually stocked without any distinction. The plant was working with a capacity of 100 tons per day. The ground ore fed to the flotation was reduced in size to d80: -150 µm, after a series of crushing, screening, grinding and classifying stages. There are 6 flotation cells as selective flotation, 6 flotation cells as the first cleaner stage, 4 flotation cells as the second cleaner stage and 9 flotation cells as the third cleaner stage in the plant. The reagents used in flotation process of the plant are lime ($CaCO_3$) as pH regulator, sodium silicate (Na_2SiO_3) as depressant, copper sulfate ($CuSO_4$) as activator, potassium amyl xanthate (PAX) and potassium ethyl xanthate (PEX) as collector and pine oil as frother. The Zn grade of the rougher concentrate in the plant was 25%. The major metal analysis of the feed material determined by atomic

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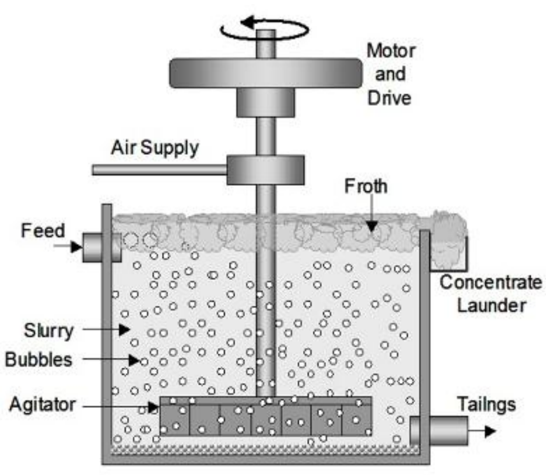
absorption spectroscopy (AAS) is given in Table 1, with Zn grade of 3.27%.

TABLE 1. ELEMENTAL METAL ANALYSIS OF THE FEED MATERIAL

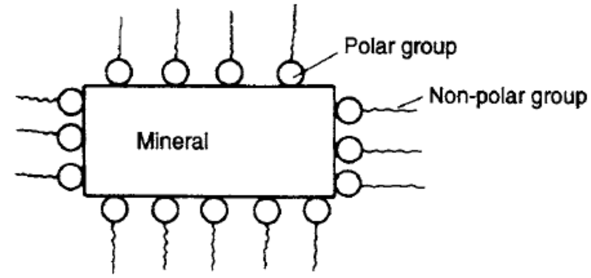
Element (Feed)	Amount (%)
Zn	3.27
Mn	0.27
Fe	26.84
Cu	0.03
Ni	0.01
Pb	0.01

Flotation is a complex physical and chemical process that occurs at the surface of mineral particles and air bubbles in the flotation pulp. The basis of froth flotation is related to the difference in surface wettabilities of the different minerals; those that are easily wettable by water are hydrophilic, those that are water repellent are hydrophobic. The process involves collisions between particles and their interaction with air bubbles in the pulp. When air is bubbled through a mixture of hydrophobic and hydrophilic particles suspended in water, the hydrophobic particles will tend to attach to the air bubbles and float to the surface. The froth layer on the surface of the flotation cell either overflows the lip of the cell or is removed by a froth scraper (Fig.1a). The hydrophilic particles which are less inclined to attach to air bubbles remain in suspension and are ultimately removed from the flotation cell in the tail [5]–[9].

It is often necessary to enhance the hydrophobicity of one or more desired mineral phases in the ore while promoting the hydrophilic character of the remaining phases. Mineral surface hydrophobicity is promoted by the attachment of collector molecules [8]. Collectors generally have a polar end with an ionic group that attaches to the particle surface and a long non-polar tail that attaches to the bubbles (Fig.1b). The selectivity of the collector for the desired mineral is partially controlled by the type of ionic group attached to the non-polar tail [7], [8], [10].



(a)



(b)

Fig. 1. a) Collector adsorption on mineral surface [7], b) Elements of a conventional flotation cell [9]

Along with collectors, other chemicals called modifiers are added to the solution to increase the recovery of the target particles. Modifiers include: activators, depressants, dispersants and pH regulators. Activators chemically change the surface of the target particles to aid in the attachment of the collectors. A depressant is a reagent which inhibits the adsorption of a collector on a given mineral or is adsorbed on the mineral to make the surface hydrophilic. Some of these include inorganic depressants such as lime, sodium cyanide, sulphur dioxide, zinc sulphate, sodium sulphate etc., and organic depressants such as acetic acid, oxalic acid and polyacrylamide polymers containing various functional groups etc. The pH of the flotation system is controlled using pH regulators to optimize the conditions for the promotion of collector attachment to the target particles [8], [10].

As xanthate collectors have a relatively low affinity for zinc ions, activation of sphalerite by copper ions is generally required to float sphalerite. The activation of sphalerite involves the exchange of zinc for copper ions, thus providing a surface receptive towards collector adsorption. One of the main impurities present in sphalerite is iron, which substitutes for zinc atoms in the sphalerite lattice, thus reducing the number of zinc atoms available for exchange with copper [11], [12].

III. EXPERIMENTAL STUDIES AND RESULTS

Flotation tests were conducted using a 1-liter capacity laboratory type flotation cell (Fig. 2a) with 330 g of ground ore sample in a Denver type flotation machine at 30% solid ratio and agitation speed of 1300 rpm (Fig. 2b).

In the tests, the reagent dosages for PAX and PEX as collectors were optimized while particle size of d80: -150 µm, $CaCO_3$ as pH regulator with a pH level of 10-11, Na_2SiO_3 as depressant, $CuSO_4$ as activator, pine oil as frother, solid ratio of 30% by solid, agitation speed of 1300 rpm, flotation duration of 2 minutes and conditioning time of 12 minutes in total remained constant (Table 2).

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(a)

(b)

Fig. 2. Laboratory setup for sphalerite flotation tests, flotation cell (a), Denver type flotation machine (b)

TABLE II. EXPERIMENTAL PARAMETERS FOR FLOTATION STUDIES

Constant Parameters	
pH	10-11
pH Regulator	Lime
Flotation Duration	2 minutes
Conditioning Duration	5+3+3+1 min. (12 min. in total)
Agitation Speed	1300 rpm
Particle Size	-150 µm (d_{80})
Solid/Liquid Ratio	30% by solids
Depressant	Na_2SiO_3, 1000 g/t
Activator	$CuSO_4$, 500 g/t
Frother	Pine Oil, 50 g/t
Determination of Frother Dosage	
Frother (PAX + PEX)	0+150, 100+50, 200+100, 300+0, 400+200, 500+250, 700+350

The results of the flotation tests for seven different mixtures of PAX and PEX are illustrated in Fig. 3. It can be observed that with increasing collector dosage, both grade and recovery for Zn starts decreasing which is due to the diminished froth formation with higher amount of reagent. The flotation plant itself consumes 260 g/t of depressant, 1843 g/t of activator, 346 g/t of frother and 1000+500 g/t collector mixtures while giving an output of 25% Zn concentrate with inadequate recovery values in rougher stage. In comparison to the processing plant real data, a rougher concentrate with 34.23% Zn grade and 96.45% Zn recovery was produced after parameter screening tests for collector dosages.

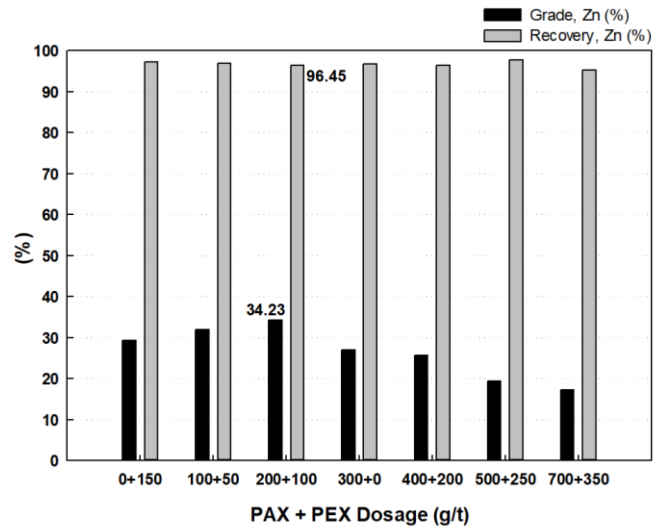

Fig. 3. Zn grade and recoveries achieved in collector dosage determination flotation tests for sphalerite

IV. CONCLUSION

One of the flotation parameters of a sphalerite ore from vicinity of Izmir, Turkey; the collector dosages was optimized in this study. The flotation process in the plant which is carried out under the specified conditions, the rougher flotation circuit can produce 25% Zn grade with low recovery values. The rougher concentration obtained in the laboratory experiments is 34,23% Zn with 96,45% recovery. It is revealed that the amount of activator, collector and frother should be lowered while the depressant dosage should be enhanced in the plant. The excess reagents used by the plant cause both flotation to be inefficient and costs to rise. The necessity of optimization by parameter screening in operating parameters is presented.

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