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The Effect of Reagent Addition Points and Aeration on the Flotation Performance of Sulphide Minerals

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ABSTRACT: Several different reagents have been used in flotation process all around the world. Flotation response of minerals could be changed not only by the type of reagents used in the plant but by the addition points of these reagents also. Therefore, it is important to determine the most appropriate reagent addition points in the flotation plant in order to obtain the best metallurgical results. In this study, flotation tests were performed in order to determine the effects of reagent addition points and aeration on the flotation behaviour of sulphide minerals. Collector and lime were added together or separately before grinding or after grinding at the flotation tests. Moreover, flotation pulp was aerated in two tests in order to determine the effect of aeration. It was found that the pulp potential changed significantly as the collector and/or lime addition points were changed. Also, the flotation behaviour of ehalcopyrite, pyrite and sphalerite was affected by the changes in the reagent addition points and aeration. Not only the copper grade and recovery of Cu rougher concentrate were affected but also chalcopyrite-sphalerite and chalcopyrite-pyrite selectivity was considerably affected. It was concluded that both reagent addition points and aeration affected the flotation behaviour of sulphide minerals in different ways. Hence, the selection of reagent addition points in a flotation plant was very important that it affects the recovery and the selectivity in the flotation of sulphide minerals. The subject has to be studied in detail in order to obtain the best results in the plant.

1 INTRODUCTION

Froth flotation has been used in the mineral processing industry since the mid-1800's with many of its broad-based applications to mineral recovery extensively developed between 1900 and 1925. Today, at least 100 different minerals, including almost all of the world's copper, lead, zinc, nickel, silver, molybdenum, manganese, chromium, are processed using froth flotation. In 1997, the estimated worldwide mineral production, using froth flotation, was two billion tons.

The mineral industry requires the use of a wide variety of both inorganic and organic chemical reagents for its operation. The reagents most commonly used in mineral processing range from chemicals used in froth flotation, grinding aids, flocculants, dewatenng agents, dispersants, solvent extraction and leaching chemicals to binding agents in pelletizing plants. However, flotation reagents predominate over any other mineral industry chemicals because the flotation process has become the single most important method for the separation of minerals from ores (Fuerstenau and Urbina, 1987).

Both inorganic and organic compounds are used extensively in flotation processing. Inorganic chemicals are added to regulate pH, to control the surface charge on minerals, to complex ions, to prevent collector adsorption and to regulate flocculation and dispersion. Organic reagents are added mainly to control wettability and the frothing behaviour of the system. The selective adsorption of collectors is directly responsible for making mineral surfaces hydrophobic. More recently, organic compounds are being utilized as depressants (Bogusz et al., 1997; Bulatovic, 1999; Drzymala et al., 2002).

Huge amounts of these reagents are used in flotation plants all over the world. Therefore, it is very important to use the appropriate reagents conveniently in the plant in order to minimize the consumption and hence the cost of the process.

Aeration of pulps at complex sulphide ores also affects the flotation behaviour of sulphide minerals as well as selectivity (Kylmowsky and Salman, 1.970). Therefore, aeration tanks are used at many flotation plants after grinding in order to improve the selectivity between sulphide minerals (Konigsmann, 1973).

It was reported that aeration improved the flotation of sphalerite while depressing pyrite (Ek, 1985; Bulatovic and Wyslouzil, 1985). Hout and Duhamet (1990) showed that both grade and recovery of sphalerite concentrate were increased as the aeration was extended. The beneficial effect of aeration on sphalerite flotation resulted as the activation by copper sulphate advanced by aeration. It was also found that dissolved oxygen concentration of flotation pulps affects considerably the adsorption rale of xanthate on both pyrite and chalcopyrite (Kuopanporatti et al., 1997). Similarly, it was observed in a study performed by using Küre copper ore that the oxidation state of pyrite and chalcopyrite surfaces and the stability of oxidation products on the surface of these minerals changed by the extended aeration and the recovery and selectivity of flotation affected significantly (Ekmekçi and Hassoy, 1999). It can be concluded that the flotation behaviour of sulphide minerals can be controlled by adjusting dissolved oxygen content of the flotation pulp (Berglund and Forrsberg, 1988).

In this study, the effects of reagent addition points and aeration on the flotation behaviour of sulphide minerals in a complex sulphide ore were studied in detail. Flotation test were performed by adding reagents at different stages and by applying aeration after grinding. Consequently, the flotation behaviour of chalcopyrite, sphalerite and pyrite at Cu rougher flotation was assessed on the basis of recovery and grade as well as flotation rate. Besides, chalcopyrite-sphalerite and chalcopyrite-pyrite selectivity were calculated.

2 EXPERIMENTAL

2./ *Material*

In this study, a complex sulphide ore obtained from the Çayeli Bakır İşletmeleri A.Ş.. Turkey was used. It is the plant feed of CBİ Cu/Zn flotation plant and consists of mainly chalcopyrite, sphalerite and pyrite. The average feed grade of the ore is 4.5 % Cu and 4.2 % Zn.

The reagents used in the flotation tests were lime (CaO) as pH regulator, di-isobutyl dithiophosphinate (Aerophine 3418A) as collector and methyl iso-butyl carbinol (MIBC) as frother. All of these reagents were obtained from the CBİ Cu/Zn flotation plant and prepared freshly before each test.

2.2 *Flotation tests*

The ore was ground in a rod mill to 70 % passing 36 microns. The pulp was directly transferred to the 2 lt. flotation cell after grinding and flotation test was performed for ten minutes with a Humboldt Wedag flotation machine. Six separate concentrates were collected at 15 sec, 30 sec, I min., 2 min., 5 min. and 10 min. intervals. The pulp pH was adjusted to nearly 11.8 before flotation at all the tests.

The chemical analysis of the products was done using atomic absorption spectrophotometer for Cu, Zn and Fe. The redox potential, dissolved oxygen concentration and pH were recorded continuously throughout the flotation tests. The parameters kept constant during flotation tests were given in the Table I.

Table I. Flotation Test Parameters

Parameter	Property
Flotation Machine	Humboldt Wedac
Cell Volume	2000 ml (plexiglass)
Sample Weight	- 1000 g
Pulp Density	36 %(v/v)
Grinding Time	55 min.
Impeller Rale	1250 rpm
Reagents	Lime (added as solid) Aerophine 3418A(1%) MIBC (added pure)

The reagents were added at the different stages of the tests. Furthermore, the pulp was aerated at some of the tests for 20 min. before flotation.

Also, a flotation test was conducted with the pulp sample taken from the secondary cyclone overflow which was pumped to the feed box of Cu rougher tlotation circuit in the plant. In this test, no reagent was added because lime and collector were added together into the mill.

The flotation test conditions were summarized in the Table 2.

Table 2. Flotation Test Conditions

Test No	Test Conditions
1	Test with the pulp sample taken from the secondary cyclone overflow. No reagent was added.
2	Lime and collector were added after grinding.
3	Lime was added into the mill and collector was added after grinding.
4	Both lime and collector were added into the mill.
5	Lime was added after grinding. Then pulp was aerated and collector was added after aeration.
6	Lime was added into the mill. Collector was added after the aeration.

3 RESULTS AND DISCUSSION

Flotation tests were evaluated from the point of view of the flotation behaviour and flotation rate of chalcopyrite, sphalerite and pyrite. Also, a selectivity index was used in order to determine the selectivity between chalcopyrite-sphalerite and chalcopyrite-pyrite.

3.1 Chalcopyrite

The effect of reagent addition points and aeration on the flotation behaviour of chalcopynte was shown in Figure I.

It can be seen that the best metallurgical results were achieved when the pulp was aerated before flotation (Tests 5 and 6). On the other hand, both Cu grade and recovery were considerably low when no reagent was added into the mill (Test 2). It is noteworthy that aeration affects the flotation behaviour of chalcopynte significantly by improving the metallurgical results (Fig. I).

It has been shown that the flotation of chalcopynte improved at high pulp potentials (Trahar, 1984; Richardson and Walker, 1985; Tolley et al., 1996; Yuan et al., 1996). Therefore, as the pulp potential increased to more oxidizing potentials by aeration, the oxidation of collector on chalcopyrite surfaces enhanced which then resulted to an increase at copper recovery.

Moreover, it can be said that the surfaces of pyrite particles were coated with hydrophilic metal hydroxides by aeration which hindered the interaction of pyrite surface with the collector in the pulp. Hence, the copper grade of Cu rougher concentrate was higher when the pulp was aerated before flotation. There are many plants around the world using aeration tanks before flotation in order to depress pyrite by oxidizing the surfaces (Berglund and Forrsberg, 1988; Ekmekçi and Hassoy, 1999).

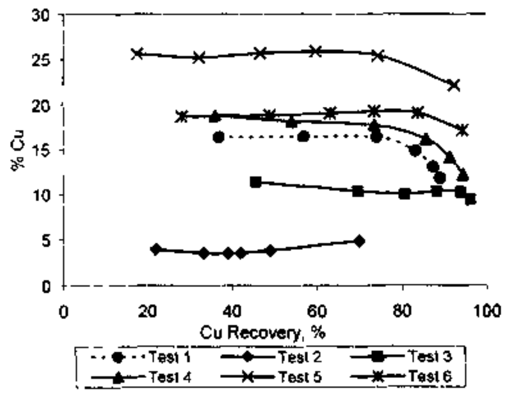

Figure I. Flotation behaviour of chalcopyrite in different test conditions

Although the overall recovery and grade was highest when the pulp was aerated before flotation, the flotation rate of chalcopyrite was rather slow at the beginning of the flotation (Fig. 2). Aeration may caused the formation of metal hydroxides on the surface of chalcopynte (Senior and Trahar, 199I) which makes the formation of metal xanthates on the chalcopyrite surface difficult resulting slow flotation rates at the beginning.

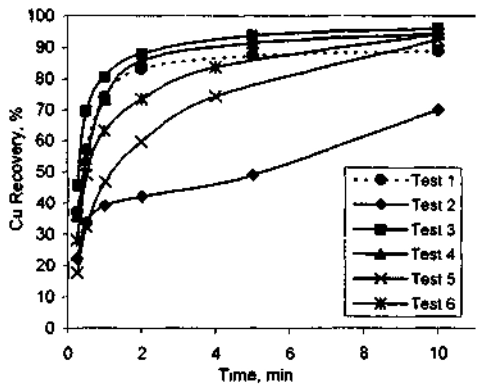

Figure 2. Flotation rate of chalcopyrite in different test conditions

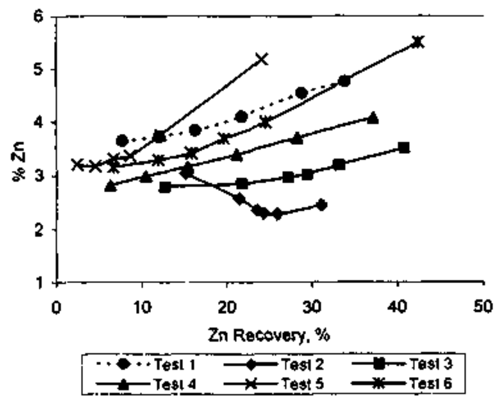

Figure 3. Flolution behaviour of sphalerite in different test conditions

As seen from Figure 3, the flotation behaviour of sphalerite was quite different from chalcopyrite. The zinc recoveries were around 35-40% at all tests except the test in which no reagent was added into the mill and pulp was aerated before flotation (Test 5). The highest zinc grade and recovery were obtained when the lime was added into the mill and pulp was aerated before flotation (Test 6). The zinc grades of concentrate was not changed at all tests and remained same as the zinc grade of feed (Fig. 3).

The flotation rate of sphalerite was faster when lime was added into the mill (Test 3) and also when no reagent was added into the mill (Test 2). When both lime and collector were added into the mill (Test 4), the flotation rate of sphalerite was nearly same as the test performed with the pulp taken from the flotation feed (Test I) (Fig. 4).

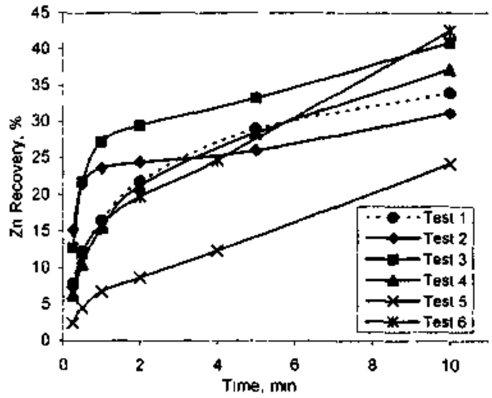

Figure 4 Flotation rate of sphalerite in different test conditions

It was observed that the flotation of sphalerite improved at more anodic potentials (Berglung and Forssberg, 1988: Labonte et al., l990rBerglund, 1991; Boulton et al., 2001), so the zinc recovery increased when the pulp was aerated. But the effect was more pronounced when lime was added into the mill (Test 6). It can be said that copper hydroxides precipitated on sphalerite surfaces acted as a source of copper ion and increased the activation ol sphalerite (Wang et al., 1989a. b) when lime was added into the mill. Besides, as the pulp was aerated, more copper ions dissolved from chalcopyrite which caused inadvertent activation of sphalerite (Yuan el al,, 1996).

3.2 Pvrite

The recovery of pyrite at the Cu rougher flotation increased when lime was added into the mill (Test 3) and also when no reagent was added into the mill (Test 2). It is noticeable that the amount of pyrite reported to the concentrate was lowest at the Test 5 where no reagent was added into the mill and the pulp was aerated before flotation (Fig. 5). It can be seen that when both lime and collector were added into the mill (Test 4), the results were same as the test performed with pulp taken from the flotation feed (Test 1). Here, it must be considered that lime and collector were added into the mill and the pulp was pumped directly to the feed box of Cu rougher circuit in the plant.

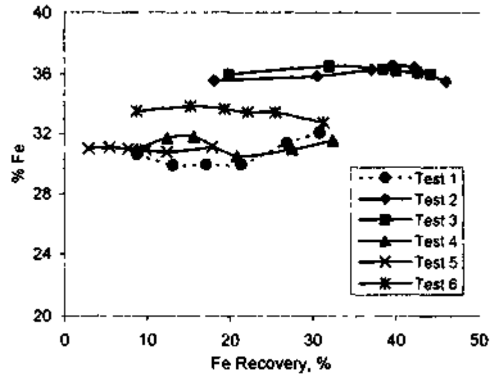

Figure 5. Flotation behaviour of pyrite in diltèrent test conditions

Similarly, the flotation rate of pyrite was faster when lime was added into the mill (Test 3) and when no reagent was added into the mill (Test 2) (Fig. 6). The flotation rate of pyrite was very slow when no reagent was added into the mill and pulp was aerated before flotation (Test 5).

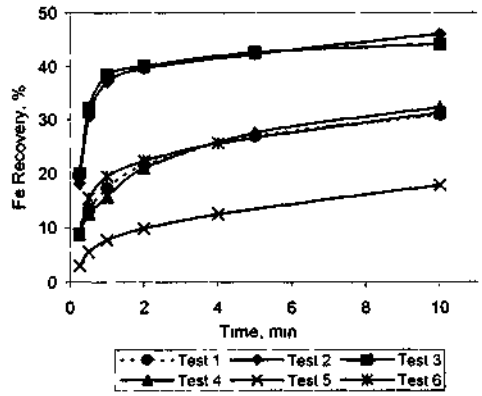

Figure 6 Flotation rate of pynte in different test conditions

It is obvious that the flotation of pyrite retarded when the pulp was aerated. Pyrite is one of the more easily oxidized sulphide mineral while chalcopyrite and sphalerite oxidation is rather slow (Hayes et al., 1987; Buckley et al., 1989). It is well known that oxygen promotes not only the anodic dissolution of minerals but also the formation of metal hydroxides in solution that, with time, will eventually precipitate on the mineral surfaces (Shen et al. 1998). The formation of metal hydroxides which are highly hydrophilic on pyrite surfaces hindered the interaction of collector with the surfaces (Shannon and Trahar, 1986).

3.3 Selectivity between minerais

Selectivity index between chalcopyrite-sphalerite and chalcopyrite-pyrite were calculated using Eq. (I) (Broadbent. et al.. 2000).

$$SI = \frac{100 - R_{Py}}{100 - R_{Cp}} \times \frac{G_{Py}}{G_{Cp}} \quad (1)$$

Here ;

Rt'n: Recovery of valuable mineral
Rp$_v$: Recovery of gang mineral
Gci> : Feed grade of valuable mineral
Gp$_v$: Feed grade of gang mineral

It is helpful to use this selectivity index because variations in the feed grade at the flotation tests can be eliminated. So, more accurate comments can be done about the results.

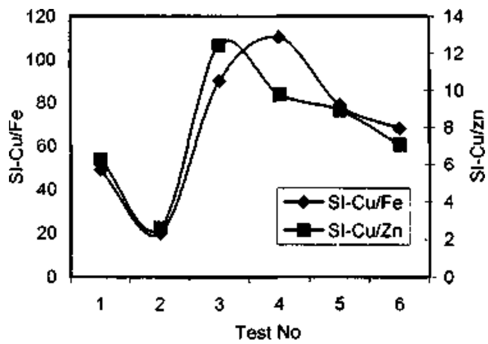

Figure 7. Selectivity index between minerals in Cu rougher flotation

It can be seen that the selectivity between chalcopyrite and sphalerite was most favourable at Test 3 where lime was added into the mill (Test 3) while best selectivity between chalcopyrite-pyrite was achieved when both lime and collector were added into the mill (Test 4) (Fig. 7).

4 CONCLUSIONS

As a result of this study, following conclusions can be drawn;

- The flotation behaviour of chalcopyrite, pyrite and sphalerite was affected by the changes in the reagent addition points and aeration.
- Aeration increased the pulp potential to more anodic values where chalcopyrite dotation enhanced.
- Sphalerite flotation improved when lime was added into the mill and pulp was aerated before flotation.
- The amount of pyrite reported to the Cu rougher concentrate decreased when pulp was aerated before flotation.
- Reagent addition points and aeration also affected the selectivity between sulphide minerals significantly.

Consequently, the results indicated that the selection of reagent addition points in a dotation plant is so important that it affects the metallurgical results of the flotation process as well as the selectivity among the sulphide minerals. Thus, the subject has to be studied comprehensively in order to obtain the best metallurgy in the plant.

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