Possibility of sodium cyanide elimination from a flotation process

Ahmad K. Darban, Hossna Darabi, M. R. Shaverdi, Amin Khodadadi

Abstract: In base metals concentration using flotation technique, pyrite decreases the quality of metal concentrates and increases the amount of sulfur compounds. To avoid low efficiency, depression of pyrite (FeS2) is essential. Flotation tests were conducted using four mixed collector systems (Aero238+SIPX, Aero3477+SIPX, TC1000+SIPX and X231+SIPX) and two depressant systems (sodium cyanide – zinc sulphate and dextrin–zinc sulphate). Also MIBC and lime were used as frother and pH regulator respectively. Taknar Cu-Zn sulphide ore was used as feed for flotation tests. This feed contains Chalcopyrite, sphalerite and pyrite with 4, 4 and 8 percent respectively. Cu and Zn contents were 1.26 and 3.5 percent. The results have shown that, dextrin is a suitable depressant for pyrite and sphalerite in the first stage of flotation. When cyanide was used as pyrite depressant, chalcopyrite recovery was decreased approximately 2% at the first stage, and copper sulphate consumption raised approximately 90 g/t for activation of sphalerite at the second stage. From Environment and HSE points of view, dextrin is natural, bio-degradable, non-toxic while cyanide is very high toxic.

Key-Words: Flotation, pyrite depressant, dextrin, sodium cyanide

1 Introduction

Flotation (historically spelled floatation) involves phenomena related to the relative buoyancy of objects. Flotation process (flotation separation) is a method of separation widely used in the wastewater treatment and mineral processing industries. Schematic presentation of flotation method is presented in Fig. 1.

Pyrite (FeS2) is present in base metal sulfides and decreases the quality of base metal concentrates and increases the amount of sulfur compounds produced in the base metal extraction processes. Therefore, depression of pyrite is necessary in the flotation concentration of sulfides. This can be achieved by floating in alkaline solutions (lime), using highly selective inorganic modifiers such as sulfites, ferrocyanides and cyanides [1-2]. To reduce plant-operating cost, alternative reagents could be used to provide mineral separations in less alkaline pH conditions [3]. In addition of modifiers, some collectors can induce selectivity against pyrite and sphalerite. The main function of collectors is to induce selectivity of desired mineral. The use of surfactant mixtures as collector can have a synergistic effect over the single collector using [4]. Of all the minerals studied thus far, pyrite depression with cyanide is the best understood. Eligil and Fuerstenau (1968) showed that the flotation recovery of pyrite can be depressed in the presence of cyanide ions by the formation of ferrocyanide ions. Although there is a general agreement on the mechanism by which cyanide depresses pyrite, the mechanism by which it depresses the flotation of sphalerite is not well understood yet [5]. Buckley et al (1989) observed that, cyanide didn’t react with zinc or sulphur on the sphalerite surface but that the copper present on the surface was dissolved [6]. Despite all mentioned about cyanide, their usage has raised concern on
environmental grounds [7]. Non– toxic and natural polysaccharides are worth investigating as alternative pyrite depressants. Polysaccharides are strong depressants in selective flotation of sulphide minerals, and they have attracted considerable attention through experiments [8]. For example, Liu and Lakovski (1989) used dextrin in chalcopyrite – galena separation, Drzymala et al (2003) used dextrin for separation of galena from copper containing minerals [9], Rashchi et al (2003) compared action of DETA, dextrin and carbonate to depress the lead ion effect on sphalerite activation [10] and Valdivieso et al (2004) used dextrin as pyrite depressant. Dextrin is one of starch derivatives which is more branched with smaller molecules. Depression mechanism of dextrin proposed to be due to the interaction between hydroxyl groups unit and metal hydroxides on sulphide surface [1]. The aim of this study is to evaluate dextrin as an alternative of cyanide in pyrite depression, when mixed collectors are used for better selectivity between minerals.

2 Material and methods

2.1 Ore characteristics

A complex Cu – Zn massive sulphide ore, containing 3.5% Zn and 1.26% Cu was obtained from Taknar mine in Iran. It was crushed to – 2 mm at the lab using a roll crusher, homogenized and riffled to 1100 g lots and milled using a batch ball mill. The mill product of 550 g with d80=95 micron was used for the first stage of floatation. Optical mineralogy, semi – quantitative x-ray diffraction (SQXRD) and x-ray fluorescence (XRF) techniques applied for ore characterization (tables 1 and 2). Table 1 shows that, main gangue mineral were quartz, magnetite and illite.

Table 1. mineralogical composition of the feed using SQXRD

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Quartz</th>
<th>Magnetite</th>
<th>Illite</th>
<th>Pyrite</th>
<th>Chlorite</th>
<th>Sphalerite</th>
<th>Chalcopyrite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent</td>
<td>33</td>
<td>20</td>
<td>18</td>
<td>8</td>
<td>7</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 2. Chemical composition of the feed sample using XRF

<table>
<thead>
<tr>
<th>Component</th>
<th>SiO2</th>
<th>Al2O3</th>
<th>Fe2O3</th>
<th>CaO</th>
<th>Na2O</th>
<th>K2O</th>
<th>MgO</th>
<th>TiO2</th>
<th>MnO</th>
<th>Fe2O5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (%)</td>
<td>44.33</td>
<td>18.73</td>
<td>22.85</td>
<td>0.27</td>
<td>0.87</td>
<td>2.64</td>
<td>1.83</td>
<td>0.18</td>
<td>0.15</td>
<td>0.13</td>
</tr>
</tbody>
</table>

2.2 Flotation tests

A Denver floatation machine, a 1.6 lit floatation cell and tap water were used for the batch floatation tests. Chalcopyrite and sphalerite floatation experiments were carried out at about 30% and 25.5% solids respectively. The impeller speed was set at 900 rpm and the air flow rate was 4.5 dm3min⁻¹. In the first and second stages, pH (8-12) adjusted using lime. Methyl Isobutyl Carbynol (MIBC) was used as frother. Recovery of Cu and Zn calculated as: M recovery(%) = (C*eM)/(F*fM)*100, where C, F, cM and fM are concentrate weight (gr), feed weight (gr), amount of metal (M=Cu or Zn) in concentrate (%) and amount of metal in feed (%).

2.3 Reagents and conditioning at the first stage of flotation

In this stage, Chalcopyrite (CuFeS2) was selectively floated and sphalerite (ZnS) –pyrite were depressed. 4 types of collector mixtures were applied of sodium iso propyl xanthate (SIPX) as stronger collector and 4 weaker collectors including: sodium di isobutyl dithiphosphate (Aero 3477), sodium secondary. Butyl dithiphosphate (Aero 238), ethyl isopropyl thionocarbamate (X231) and modified thionocarbamate (TC1000). Weaker and stronger collector used in 2:1 ratio. Sodium cyanide – zinc sulphate (ZnSO4) and dextrin – ZnSO4 were used as 2 depressant systems for pyrite – sphalerite depression. The pulp was stirred and pH was adjusted for 3 min before adding depressants. ZnSO4 and sodium cyanide added simultaneously and conditioned for 8 min. for other depressant system (ZnSO4 - dextrin), dextrin conditioned for 4 min. Weaker collector added, followed by conditioning for 5 min, and the addition of second (stronger) collector (SIPX), followed by 3 min conditioning. Then, the frother was added and conditioned for a further 1 minute. After starting the air flow, the froth was removed by hand scraping. Concentrates and tailings were dried and analyzed by atomic adsorption spectrometry (AAS). Pyrite content was measured using optical mineralogy of concentrate sections. Tailings were used for sphalerite flotation in the second stage.

2.4 Reagents and conditioning at the second stage of flotation (sphalerite flotation)

Sphalerite flotation tests carried out using tailings of the first floatation stage at 25.5% solids (465 g). After adjusting pH at desire level, the copper sulphate (CuSO4) was added as sphalerite activator, following by 8 min conditioning. SIPX was then added and the pulp was conditioned for 3 min, after
which the frother was added and conditioned for a further 1 min. Attention should turn to that, the second stage performed without adding new amounts of pyrite depressants. For the first and second stages of flotation 31 and 24 tests designed using D-Optimal method of experiment design (Response Surface Methodology of DX7 software).

3 Results and Discussions

3.1 Effect of pyrite depressant type on desired mineral (chalcopyrite) flotation recovery

Because in base metal sulphides flotation, selective flotation of desired mineral is the most important factor, reagents should be selected in the way that have better agreement with desired mineral recovery and undesired minerals depression. Fig. 2, shows the effect of mixed collector types and sphalerite – pyrite depressant systems on Cu recovery in pH=10.54. It is indicated that, using TC1000 + SIPX and Aero238 + SIPX, Cu recovery was in maximum level of 90.56% and 89.72% by either ZnSO4 – CuCN or ZnSO4 – Dextrin as depressant systems. Responsible species for surface hydrophobicity of chalcopyrite are: copper xanthate (CuX), dixanthogen (X2), copper phosphogene (Cu(DTP)2) and copper dithiocarbamate (Cu(DTC)), which dithiolate species aren’t stable in high pH values (specially above 10.5) [6]. Fig. 2 also illustrates that, compared to 2 other mixed collectors, for Aero3477 + SIPX and Aero238 + SIPX using of CuCN as pyrite depressant, decreased Cu recovery. After pyrite, chalcopyrite is the main sulphide mineral which is depressed by CuCN. For instance, in the presence of Aero238 + SIPX as mixed collector, when depressant system was dextrin – ZnSO4, Cu recovery of 89.72% obtained compared to 88.57% for CuCN – ZnSO4 system. As expected, ZnSO4 had no significant effect on Cu recovery. Compared to Dextrin as depressant, chalcopyrite recovery was decreased approximately 2% by using CuCN.

3.2 Best collector mixture for selectivity against pyrite and sphalerite

Depression of pyrite from Taknar ore can partly be achieved by using cyanide or dextrin. In addition, pyrite content in Cu concentrate can be decreased further by using collector mixtures. The effects of different mixed collectors and depressant systems on pyrite content in Cu concentrate are presented in Fig. 3 Therefore, TC1000 + SIPX and Aero238 + SIPX induced better selectivity against pyrite. Also, it has attracted considerable attention through results that, dextrin as pyrite depressant had approximately similar performance to CuCN. For example, in pH=8 (in which pyrite had good flotability), by using Aero3477 + SIPX, Aero238 + SIPX, X231 + SIPX and TC1000 + SIPX in the presence of CuCN, pyrite content in Cu concentrate was: 4.31%, 3.1%, 4.37% and 3.49% respectively, which in the presence of dextrin it was 4.51%, 3.4%, 4.14% and 3.49%. In general, pyrite depression improved in higher pH values, which was due to dithiolate instability [1].

The effects of different mixed collectors, depressant systems and ZnSO4 Dosage on Zn recovery in Cu concentrate are shown in Fig. 4. Results from fig. 4 can be summarized as: a) Zn recovery decreased with ZnSO4 increasing up to a point and after that was stable, b) in pH values about 10, maximum Zn recovery in Cu concentrate was observed and c) combined effect of CuCN and ZnSO4 was more effective in sphalerite deactivation than dextrin - ZnSO4. At similar conditions with other mixed collectors, Aero238 + SIPX and Aero3477 + SIPX had maximum selectivity against sphalerite. According to the results obtained from fig. 4, for Aero3477 + SIPX in the presence of CuCN - ZnSO4, pH=10 and ZnSO4 dosage of 350 and 500g/t, Zn recovery was 28.93% and 26.8%, respectively. At similar conditions in the presence of dextrin - ZnSO4, Zn recovery obtained 31.24% and 28.17%.

3.3 Factors affecting sphalerite flotation from first stage tailings

The effect of SIPX dosage and CuSO4 concentration on Zn recovery is shown in Fig. 5. In general, Zn recovery was more dependent on collector dosage rather than the CuSO4 concentration. In low SIPX dosages, Zn recovery was decreased with CuSO4 concentration increasing, because of precipitation of Cu(OH)2 at higher copper concentrations [11]. In higher SIPX dosages, Zn recovery was increased with CuSO4 concentration increasing to an optimum level.

It is clear that CuCN which was used to suppress the flotation of sphalerite – pyrite at previews stage of flotation have influenced Zn recovery and CuSO4 consumption at the second stage by increasing CuSO4 consumption at the same values of Zn recovery. One important effect of cyanide complexes presence in the system is that, they react with surface copper to form copper cyanide complexes. Arbiter (1985) also postulated that the cupro – cyanide complex was relatively stable and limited the concentration of free dissolved copper ions needed for sphalerite activation [12]. When
CuCN was used as pyrite depressant, CuSO4 consumption raised approximately 90 g/t for activation of sphalerite. For instance, in pH=9.5, SIPX dosage of 22.22 g/t, Zn recovery of 69.5%, CuSO4 consumption was 350 and 260 g/t when dextrin and cyanide was used for pyrite depression at the first stage, respectively. From Environment and HSE points of view, dextrin is natural, biodegradable, non-toxic while cyanide is very high toxic.

3.4 Optimization

In this research, optimization by DX7 software was done and its purpose was to reach maximum Cu recovery and minimum recovery for Zn and pyrite in Cu concentrate with minimum consumption of reagents, and maximum Zn recovery at the second stage of flotation. Maximum Cu recovery was reached to 91.46% using 200g/t ZnSO4, Aero238 + SIPX as mixed collector and pH=9.16 (optimization No. 1). These conditions observed when Zn recovery and pyrite content were 38.74% and 2.31%. In optimization No. 2, Zn recovery and pyrite content were held in minimum level. In this case, Cu recovery, Zn recovery and pyrite content were 88.99%, 33.49% and 1.34% respectively. Another important result is that, for holding Zn recovery and pyrite content in their minimum level, cyanide was better pyrite depressant and in the case where Cu recovery was important, dextrin was better. In second stage, maximum Zn recovery of 72.19% was obtained using 343.66g/t of CuSO4, 22.22g/t of SIPX in pH=9.99. In both optimization conditions, dextrin has had better effects on subsequent sphalerite flotation.

4 Conclusion

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References:
Fig. 2. Effect of mixed collector and depressant system types on Cu recovery (pH=10.54 and ZnSO4 dosage of 350 g/t)

Fig. 3. Effect of mixed collector type and depressant system type on pyrite content in Cu concentrate (pH=10.54, ZnSO4=350 g/t)

Fig. 4. Effect of mixed collector types and ZnSO4 dosage (g/t) in pH=10.54 on Zn recovery using different depressant systems: A) CuCN – ZnSO4 and B) Dextrin – ZnSO4.