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Research Paper

Investigation of Parameters Affecting Sulfide–Oxide Copper Flotation at the Cheshmeh Hadi Mine

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***Abstract*:** A study of the processing of copper sulfide-oxide ore by sulfidation and flotation with xanthate was conducted for a sample from the Cheshme-Hadi mine located in Bardaskan city, Razavi Khorasan province. The copper content in this soil was 0.65%, of which 70% was in the form of copper oxide minerals, including malachite and, to a lesser extent, azurite and atacamite, and the rest was in the form of copper sulfide minerals, including chalcocite and bornite, and waste minerals of aluminosilicates and clays. The results showed that by increasing the pH to 11 for copper oxide and 10.5 for copper sulfide, copper recovery increases. Separate flotation of copper sulfide and copper oxide did not significantly improve copper recovery. If lime and activator are added to the flotation, the sulfidation process of copper-bearing minerals is better, which increases the recovery of copper oxide. The optimal conditions for copper oxide recovery in the Cheshme-Hadi mine were obtained as follows: 100 g/ton amyl xanthate, pH 11 and 1000 g/ton sodium sulfide, solids percentage 30%, grinding time 15 minutes (d80=65 µm). Under these conditions, the recovery of copper oxide, sulfide and total copper was 76, 82 and 79%, respectively.

Keywords: Cheshme-Hadi mine, Flotation, Sulfidation, Collector, Copper oxide minerals.

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INTRODUCTION

Copper oxide minerals do not respond well to the chemicals used to separate copper sulfide minerals. In this case, the collector consumption is high, and the selectivity and recovery are low. The solubility of copper oxide and sulfide minerals is significantly different, with copper oxide minerals having higher solubility. The low mechanical strength of the surface of oxidized minerals can be demonstrated by flotation of malachite using xanthate. In this case, the recovery of malachite is very low [1]. Flotation of oxide minerals depends on many parameters, such as the electrical properties of the mineral surface [1,2], the molecular weight of the collector, the solubility of the mineral, the possibility of forming a collector salt, and the solubility of this salt [1]. These minerals have low flotation ability due to their high clay content [1], high fines production [1,3], association with iron oxides [1], and contact with sulfide deposits. One of the biggest problems of copper oxide flotation on an industrial scale is that the flotation ability of these minerals is strongly dependent on the mineralogy of the deposit and the composition of the tailings. The flotation ability of copper oxide containing carbonate and dolomitic tailings is significantly different from the flotation ability of copper oxide containing silicate tailings [4]. Despite these problems, in recent years, due to the decline in copper resources, the use of copper oxide deposits has received attention [4-6].

Copper extraction from oxide ores, if their tailings are not carbonated, is usually carried out by acid leaching, but due to the high acid consumption of carbonate minerals such as calcite and dolomite, it is practically not possible to recover copper from them by acid leaching, and alkaline leaching methods have not found industrial application due to the problems related to the recovery of copper from alkaline leaching solution. In addition, if the copper-bearing ore is of the sulfide-oxide type, it is practically not possible to recover copper from it by leaching because the dissolution of copper from sulfide minerals under atmospheric leaching conditions has a very low efficiency, and the overall leaching recovery is greatly reduced [7].

In recent years, the use of flotation for the enrichment of copper sulfide-oxide ores [3,6-8] and copper oxide ores with carbonate tailings has received much attention, because it does not have the limitations of the leaching method [7].

In general, there are two common methods for the flotation of copper oxide minerals:

1. The method without activation and the direct use of oxyhydryl anion collectors such as fatty acids, amines and hydroxamates, which is usually used for copper oxide ores with carbonate tailings.

2. Activation by sulfidation using various chemicals such as sodium sulfide, sodium hydrosulfide and then flotation of the activated minerals using xanthate collectors, which can be used for most copper oxide ores [2,7-9].

The sulfidation and flotation method with xanthate is the most widely used method for sulfide-oxide copper ores [10-13] and has high selectivity, but the amount of sulfidating agent used must be carefully controlled, which is difficult. The main problem of the sulfidation process is that the appropriate and optimal concentration of the sulfidating agent is highly dependent on the preparation time, mixing methods, etc. [14]. In addition, the flotation behavior of copper oxide minerals depends on the mineral composition, the ratio of oxide to copper sulfide minerals, and the ionic composition of the pulp [8,14].

The aim of the present study is to process a sulfide-oxide copper ore by sulfidation and flotation with xanthate.

METHODS

To investigate the effect of the operational parameters, 36 experiments, including 6 replications, were designed based on the Box-Behnken model. The results obtained from the experiments were entered into the experimental design software (DX7). The flotation experiments were conducted using chemicals used in the Taknar copper plant in the Cheshme Hadi Mine. Z6 ($C_6H_{11}KOS_2$) and Z11 ($C_4H_7NaOS_2$) collectors are from the xanthate group, which have higher recovery than carbamates and dithiophosphates, but their concentrate grade is lower. MIBC ($C_6H_{14}O$) is also the most common industrial foaming agent. Lime ($CaCO_3$) was used to adjust the pH, and sodium sulfide (Na_2S) and sodium hydrosulfide (NaHS) were used to activate copper oxide minerals. The flotation experiments were conducted using an existing flotation cell with a volume of 1000 ml. The pulp required for each experiment was transferred to the flotation cell with 350 g of solids after grinding and a solids percentage of 30%. The order of adding the reagents was as follows: first, lime was added to the flotation cell to adjust the pH of the pulp to the desired value. One minute was given for the pH of the pulp to stabilize. Then, the activator was added to the flotation cell and prepared for 5 minutes. Next, the collector was added to the flotation pulp, and stirring was continued for two minutes. Finally, the frother was added to the flotation cell in an amount of 0.25 ml (35 g/ton), and after one minute, the foaming was performed. The foaming was continued until the foam turned white (4 minutes). Finally, the concentrate and tailings were placed in separate containers in an oven at a temperature of 85 °C until they were dried. Then, the concentrate and tailings were powdered by a pulverizer and transferred to the laboratory for copper sulfide-oxide analysis.

FINDINGS AND ARGUMENT

Although longer hydrocarbon chain xenonate collectors perform better in the flotation of copper sulfide-oxide ores due to their higher collector strength, the use of potassium amyl xenonate collector had a better effect on the recovery and grade of the process compared to sodium isopropyl xenonate collector, according to the models presented in this research.

The copper sulfide minerals present in a copper sulfide-oxide ore were not floated by the xenonate collector alone, and the need for a sulfidation agent is low. The reason for this is the partial oxidation of the surface of copper sulfide minerals in this type of ore.

To optimize the flotation, the conditions for achieving maximum grade and recovery of copper were selected. The results of the optimization of the responses are shown in Table 1.

Table 1. Results of optimization of responses

<table>
<tr><th>Flotation</th><th>Goal</th><th>pH</th><th>Collector (g/t)</th><th>Sodium sulfide</th><th>Solid percentage</th><th>Copper grade (%)</th><th>Copper recovery (%)</th></tr>
<tr><td>Sulfide</td><td>Maximum recovery</td><td>10.5</td><td>100</td><td>-</td><td>30</td><td>16.07</td><td>82</td></tr>
<tr><td rowspan="2">Oxide</td><td>Maximum recovery</td><td rowspan="2">11</td><td rowspan="2">98.86</td><td rowspan="2">1000</td><td rowspan="2">30</td><td rowspan="2">14.39</td><td rowspan="2">76</td></tr>
<tr><td>Maximum grade</td></tr>
</table>

For each stage, two additional experiments were conducted based on the optimal conditions determined in Table 1. The actual results were very close to the predicted results. Therefore, the evaluation of the models was successfully completed.

The results of this study (soil containing 70% oxidized minerals with a copper grade of 0.65%) were in agreement with the results of Wang et al. (2013) [12] on the flotation of copper oxide ore using a combination of sodium sulfate and ethylene diamine as surface activators and xanthate as a collector (concentrate with a copper grade of 16.01% and a recovery of 74.38% for Wang et al.'s study, compared to a sulfide concentrate with a copper grade of 16.07% with a recovery of 82% and an oxide concentrate with a copper grade of 14.39% with a recovery of 76%).

CONCLUSIONS

In the Taknar copper plant that processes the feed of the Cheshme-Hadi mine, according to the screening studies and experiments, three parameters- pH, collector concentration and activator concentration- were selected as the parameters affecting the flotation of copper oxide-sulfide ore, and their values were optimized using the Box-Behnken response surface method. Other parameters were considered constant at the desired value obtained from the first stage. Thus, the grinding value was d80=65 µm, and the type of activator was sodium sulfide. The results showed that the sulfidation-flotation process with a xanthate collector is capable of the desired enrichment of copper sulfide-oxide ores. In this process, the total copper recovery is mainly dependent on the recovery of copper oxide because the recovery of copper sulfide is almost complete. By adjusting the operating conditions, a recovery of about 76% for copper oxide and a total copper recovery of about 81% are obtained, which confirms the efficiency of the sulfidation-flotation process with a xanthate collector in the enrichment of copper sulfide-oxide ores. In this process, sodium sulfide is well capable of sulfidating the surface of copper oxide minerals (malachite and azurite), and usually the desired degree of freedom in d80 is between 60 and 70 microns, which confirms the need for more crushing of this type of copper ore than purely sulfide ores. The appropriate pH for flotation is in the range of 10.5-11, and the concentration of collector and activator is recommended at 100 g/t and 1000-1500 g/t, respectively. In addition, simultaneous addition of lime and activator to the mill improves the flotation performance of copper sulfide-oxide ore. In addition, single-stage flotation can achieve the desired recovery of copper sulfide-oxide minerals, and two-stage flotation and separate production of copper sulfide and copper oxide concentrates do not increase the overall copper recovery; therefore, two-stage flotation and separate production of copper sulfide and copper oxide concentrates are not recommended.

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