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Research Paper

Selective Extraction of Cobalt, Manganese and Zinc from the Filter Cake of the Zinc Processing Plant

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Abstract: In the electrolytic extraction of zinc, the filter cake of the hot filtration process contains zinc, manganese, and cobalt. In this study, the metals were extracted by using two selective leaching steps. The results showed that at pH = 1 and 90 °C, about 88% of zinc was recovered without cobalt and manganese. In the selective leaching stage, cobalt was significantly extracted (91%) by adding hydrogen peroxide (H_2O_2) to the acidic leaching solution at pH <1. By reprecipitation of the extracted cobalt and selective leaching with H_2O_2, the solution containing cobalt ions with high purity was obtained.

Keywords: Hot filter cake, Leaching, Transition metals, Zinc plant, Waste recycling.

INTRODUCTION

Recycling transition metals like cobalt, zinc and manganese from the hot filter cake has been practiced by using conventional acid leaching and organic solvent extraction. However, the high price of the solvent and numerous multiple steps are prohibitive. There is also a possibility of environmental hazards of organic compounds [1,2]. Increasing the amount of additive H_2O_2 increases the dissolution of cobalt and manganese which are separated and extracted with solvent extraction process [3]. Further, leaching the ore containing 1.5% cobalt and 1.6% copper with a mixture of sulfuric acid and hydrogen peroxide has increased their recovery by 90% [4]. Also, selective leaching of cobalt from solid waste using weak acid along with the reducing agents like disodium metabisulfite ($Na_2S_2O_5$), sulfur dioxide, etc. has been studied [5,6].

Considering above-mentioned points, this study was aimed to extract valuable metals from the hot filter cake by using two selective leaching steps.

EXPERIMENTAL SECTION

Hot filter cake from Zanjan-Melt company was used in this research. XRF analysis indicated that the cake contained 0.9% cobalt (Co), 10.4% zinc (Zn) and 16.6% manganese (Mn). Adding potassium permanganate increased the manganese in the cake. In the zinc production process, 3.4% aluminum as $Al_2(SO_4)_3.nH_2O$ was added to neutralize the acidic leaching solution, to control fluoride, and to lower the iron content (about 0.6%). The use of lime to adjust the pH in the neutralizing step can also be the cause of high percentage of calcium (18.4%). Plus, the presence of impurities in the lime may be the reason for 2% silica in the final filter cake.

Research method

All batch experiments were performed in a 0.5 liter, 3-necked balloon flask equipped with a mechanical stirrer and reflux condenser. Sulfuric acid (H_2SO_4) was used as a leaching agent under ambient pressure. The flask was immersed in a thermostatically controlled water bath. The time was fixed on 90 minutes. And, the stirrer speed was 700 rpm to provide a stable suspension. The design of experiments (DOE) was based on 3 parameters at 3 levels. Periodically, 10 ml samples were taken from the solution, filtered and analyzed with atomic absorption spectrophotometer (AAS). Design-Expert software was used to optimize the leaching process, to provide the graphical analysis, and to determine the results of the data regression. This software has the ability to calculate and present ANOVA, degree of freedom, regression equation, 2D and 3D images, effect of each parameters with their optimal position. The considered DOE were as follows: pH at 0, 1 and 1.5; temperature at 50, 70 and 90 °C, and pulp density at 7, 10 and 15% (w/v). 27 tests were conducted in accordance with a full factorial design, the results of which were reported based on the amount of zinc and iron extraction. Then, the zinc leaching residue was separated using vacuum filtration. Afterwards, the solid residue was used as feed for the selective cobalt leaching step. This sample was analyzed with the AAS after initial preparation. The amount of manganese, cobalt and zinc remaining in the residue were 23.9%, 1.9% and 2.43%, respectively. The parameters considered for the cobalt leaching were the same as the previous stage except that H_2O_2 was added to this step at 3 levels of 0.043, 0.085 and 0.17 M.

RESULTS AND DISCUSSION

Selective leaching

Zinc. To dissolve the zinc from the cake, the parameters pH, temperature, pulp density, and the interaction of temperature and pulp density were detected to be significant. The significance of each parameter in the model indicated the correctly selected, affecting parameters. Increasing the pH from 0 to 1 had little effect on zinc dissolution. Nevertheless, the pH and temperature showed significant effect at higher pulp densities (Figure 1) (Positive interaction).

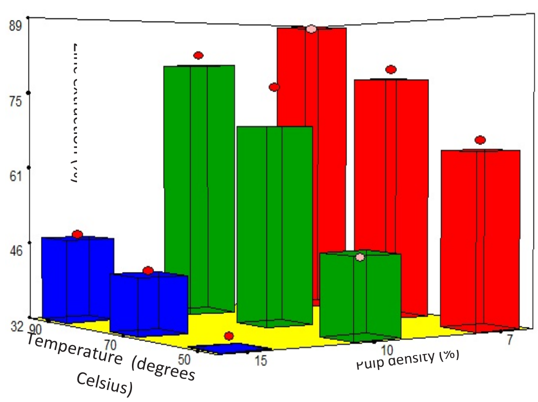

Figure 1. Interaction of temperature and pulp density on zinc extraction

In other words, as the pulp density increases, acidity becomes the most important factor for zinc dissolution (Figure 1). One reason to explain this may be that the filter cake was alkaline due to the presence of ZnO, so that at high pulp density both the soluble alkaline properties and the acid-consuming factors such as CaO were increased. As such, more acid consumption and reduced zinc extraction were resulted. In this step, leaching at high temperatures and acidities (low pHs) was not recommended because of cobalt dissolution, which reduces the purity of the obtained PLS. Additionally, the amount of the remaining cobalt in the solid residue (feed for next step) was decreased. Of course, it should be noted that if the amount of iron in the cake was high, enhanced temperatures could be an advantage because iron may be precipitated as jarosite, resulting the elimination of a large part of this impurity.

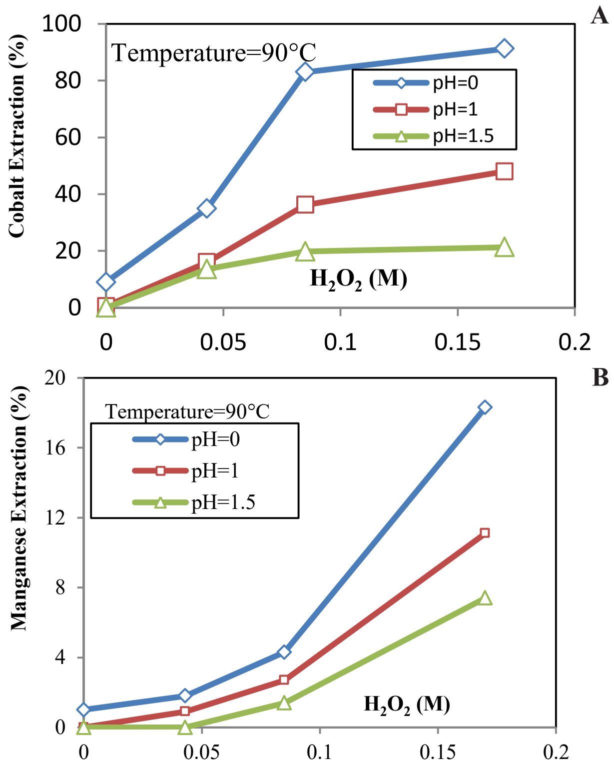

Figure 2. Effect of pH and H_2O_2 on the recovery of **A:** cobalt and **B:** manganese

Cobalt. For cobalt dissolution, the studied variables did not have a statistically significant interaction. In Figure 2-A, decreasing the pH and increasing the concentration of H_2O_2 led to further dissolution of Co. By lowering the pH (from 1 to 0), the recovery sharply improved. The pH of the PLS and the concentration of H_2O_2 were identified as the parameters affecting the dissolution of Mn in the selective leaching stage of cobalt (Figure 2-B). The solid residue from this step had a high percentage of manganese (38%) and the minor amounts of Zn (0.1 %) and Co (0.4 %).

Reprecipitation of cobalt and manganese

By adding the oxidizing agent permanganate-potassium at pH 5, Mn and Co ions were precipitated from the PLS. After filtration, the PLS contained concentrated Zn ions.

Cobalt re-leaching

To re-extract cobalt, the cake from the reprecipitation stage was leached under optimal conditions (90 °C, pH 0 and concentration of 0.1 M H_2O_2 for 90 minutes) with the selective leaching characteristics. The solution contained about 1000 ppm of cobalt ions. And, the other ions Zn and Mn were less than 10 ppm.

CONCLUSION

The optimum zinc leaching conditions were obtained at 90 ° C, 7% (w/v) pulp density, pH 1.2, and time 90 minutes. Under these conditions, 88% of zinc was leached. Optimum cobalt recovery was achieved at 90 °C, pH 0 and H_2O_2 concentration of 0.1 M within 90 minutes, in which 84.45% of Co and 6.77% of Mn were recovered. Under the optimal conditions obtained from the selective cobalt leaching stage, the solid residue was leached in the third leaching step. The final PLS contained about 1000 ppm of cobalt while zinc and manganese were less than 10 ppm.

Conflict of interest: The authors of the article have not declared any conflict of interest with respect to authorship and publication.

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