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An increase in the Copper Recovery of the Sarcheshmeh Copper Complex through Reagent Modifications

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ABSTRACT: *In the flotation of sulfide minerals, particularly in the separation between pyrite and chalcopyrite, adjustment of the pH and reagents dosages is very important. Process auditing at the Sarcheshmeh copper complex showed that the pH in the rougher cells was greater than 12, while according to the initial design, the pH in the rougher cells should be 11.5. Also, it was found that the collectors and frothers dosages were 21.6 and 25.1 g/t, respectively, which is much lower than the initial design. Also, plant audit showed that this operation method was used because of an idea about higher froth stability and easier operation in the higher pH values. In addition, it was observed that by suddenly changing the reagents and pH regime to the initial design, operation stability and therefore the copper recovery were also reduced quickly. Hence, in this study pH was decreased and reagent dosages were increased step by step. The results showed that after adjustment of the pH in the range of 11.5-11.7 and increasing the collectors and frothers dosages to 29 and 31 g/t, respectively, the copper recovery was increased by about 2%, and the operation stability was not reduced.*

KEYWORDS: *Flotation; Milk of lime; pH; Collector; Frother.*

INTRODUCTION

Flotation is undoubtedly the most important and versatile mineral separation technique [1], and both its use and applications are continually being expanded to treat greater tonnages and to cover new areas. Flotation is a separation process that exploits natural and induced differences in surface properties of the minerals, whether the hydrophilic particles can attach to air bubbles and be floated. Flotation is a selective process and it is a complex involving three phases (solids, water, and air) and the interaction of chemical and physical variables [2]. In the flotation process, the recovery of valuable particles

are related to various factors such as feed grade, feed size distribution, reagent type, dosage, and distribution regime, gas rate, feed density, pH, and residence time [3].

In the industrial scale flotation circuits, reagent control is the most important factor. Copper porphyry sulfide minerals are readily floatable and respond well to thiol collectors such as xanthates and synthetic frothers such as MIBC and polyglycol-types [4-6]. Also, the pH is controlled with milk of lime to depress pyrite [7]. It is now widely accepted that there are two separate mechanisms by which collectors adsorb on the sulfide minerals. First,

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there is the chemisorption mechanism where the adsorbed xanthate molecule forms chemical bond with metal atoms at the sulfide surface. The other mechanism is electrochemical and involves electrochemical oxidation of the adsorbed collector molecules to give oxidation product species, which renders the sulfide surface hydrophobic [4, 5]. It has been shown that the recovery is increased with collector concentration up to a maximum, and this maximum level varies with the type of collector. At a very high collector dosage, it is possible that chain-chain (hydrocarbon chain of the collector) interaction causes a second, inverted adsorption layer to form with the molecule's polar head which is exposed to the water making the surface hydrophilic. It is possible, therefore, to overdose collector and depress flotation [2, 8]. Reductions in the bubble size and the bubble rise velocity are two main functions of frothers in the flotation. Reductions in the bubble size, increases the number and total surface area of bubbles, which increases the collision rate with particles and thus increases the recovery and decreases the grade [2].

The effect of reagent dosage and the particle size distribution on metallurgical performances has been studied in detail by many researchers [9-12]. One application of these findings has been the stage-by-stage addition of the flotation reagents which has also been the focus of numerous investigations [9, 13, 14]. The rational explanation for this is the fact that fine particles have a larger specific surface area than coarse particles and the amount of collector required to produce a given degree of particle coverage per unit of mass in the fine particles is much higher than in the coarse particles. Therefore, if all of the collector is added at the top of the bank, it will be mostly consumed by fine particles which in fact need little coverage to be efficiently floated. On the other hand, there will not be sufficient collector available to produce the hydrophobic coverage required to float the coarse particles. The distribution of the collector and the frother down a flotation bank promotes the flotation of fines by the initial collector addition and the recovery of medium and coarse particles becomes possible after the second addition point. This may lead to a reduction of collector consumption and may also provide some gain in selectivity and there could be less entrainment of hydrophilic particles in the first flotation cells of the bank [9, 15].

Reagents in the flotation of porphyry copper and copper-molybdenum deposits

Porphyry copper deposits have very similar operating practices regardless of the differences in ore characteristics. Usually, in the circuits, lime is used as pH modifier and xanthates are used as primary collectors. However, there is a wide variation in the selection of the type of frother, and in many operating plants a mixture of two or more frothers are used [16]. The secondary collector type varies from operation to operation and is selected from a variety of collectors including dithiophosphates, mercaptans, thionocarbamates, xanthogen formats, etc. The main reason for this is the interference from clay minerals, which in some cases tend to produce a dry froth and therefore difficult to remove. A mixture of frothers may solve this problem. In some cases, an alcohol-type frother may give a brittle froth, which is also difficult to remove from the cells [16].

The regulation of the pulp pH is one of the essential selectivity parameters of the process of extraction by flotation of the polymetallic ores [6]. The flotation pH in the majority of copper plants is in the range of 10-12 and most often over 11 [2, 16]. But in modern copper ore mills, the pH is 10–11 units [7]. In a research it was shown that the best pH for copper flotation is 10 [17]. At Utah Copper ore mill (USA), the rougher flotation is carried out at pH 8.5, scavenging- at pH 9.5, while at Pinto Valley, Mineral Park and Bagdad ore mills (USA) the pH of the medium is 11.5 [7]. Also, it has been shown that the decrease in recovery for pH values beyond 11 may be a result of the formation of metal hydroxide as hydrophilic species [18]. Fig. 1 shows maximum copper recovery is at about pH 10-11. Also, it has been shown that the middling and the coarse particles have improved floatability at a higher pH region. This is true in the case where copper is represented by chalcocite as the major copper mineral. In the case of chalcopyrite ore, a lower pH is more desirable (i.e., 8.5–9.5) because at a higher pH, the floatability of chalcopyrite is reduced, especially in the case of the coarser particles [16].

It was shown that the relatively high pH used in operating plants is not designed to depress pyrite, but rather it can be used as a frother modifier. In reality, the higher pH produces a stable froth with better carrying power compared to lower pH for the majority of porphyry copper ores [16].

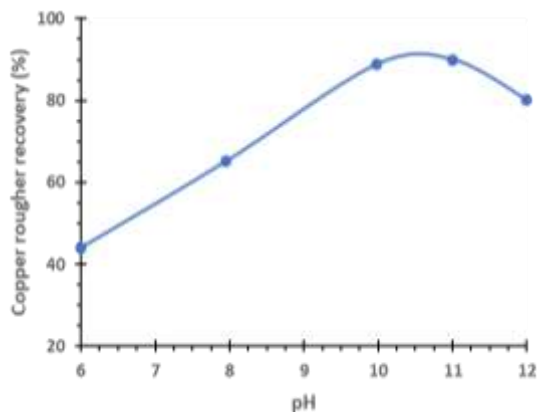


Fig. 1: Effect of pH on the copper recovery [16].

Distribution regime of reagents in the flotation circuits

The effects of the reagent dosage and the particles size distribution on the flotation performance were studied by a number of researchers [2, 9, 10, 13, 14, 19-23]. In the flotation process, there is an interaction between the collector dosage, the particles size, and the floatability. A same floatability in the fine and coarse particles is resulted from much higher amount of collector per unit of mass in the coarse particles. In other words, the fine particles are recovered with lower amounts of the collector [10]; while more amounts of collector are absorbed with fine particles because of further specific surface area than the coarse particles. Therefore, when total collector is added only before the first flotation cell, a main portion of the collector will be absorbed on the surface of fine particles; hence the recovery of coarse particles will be decreased because of the low collector absorption. Finally, it is recommended that the fine particles are recovered with a portion of the reagent at the first flotation cells, and coarse particles are recovered at the next flotation cells using distribution of reagent down a flotation bank [24]. This may lead to a reduction of collector consumption and may also provide some gain in the selectivity and there could be less entrainment of hydrophilic particles in the first flotation cells of the bank [15].

The effects of reagent distribution system on the performance of the flotation circuit of the plant No.1 of the Sarcheshmeh copper complex was studied at the bench, pilot, and industrial scales. The results showed that the replacement of the single point addition of reagents (100-0-0%) in the rougher banks with a 75-25-0% regime,

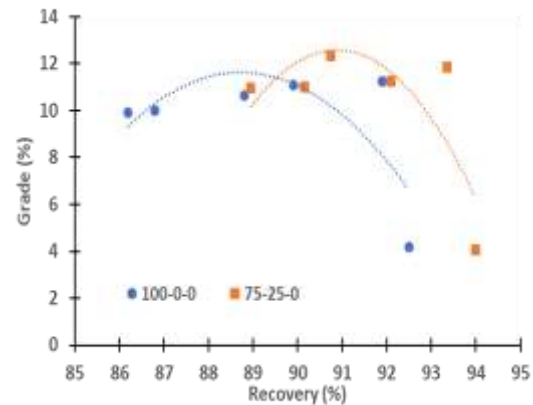


Fig. 2: Grade and recovery curves for two different reagent distribution systems [9].

increased the overall copper recovery by at least 1.3 % at a constant concentrate grade (Fig. 2) [9].

The flotation circuit of the plant No.2 of the Sarcheshmeh concentration plant

The flotation circuit consists of the roughing, regrinding, cleaning, recleaning, and scavenging stages. Re grind circuit includes a ball mill operating in a closed circuit with hydrocyclones (Fig. 3). The rougher stage in each line uses 8 tank cells, each with a capacity of 130 m³ (RCS 130). The rougher tailing constitutes most of the final tailing, and it's concentrate is combined with the scavenging concentrate and is fed to the regrind circuit. The feed to the regrind circuit is first classified by 10 hydrocyclones (38.1 cm in diameter), where the underflows are sent to a ball mill (3.9 m diameter and 5.8 m length). The hydrocyclones overflows are fed to 3 flotation cells, each with a capacity of 50 m³ (RCS 50) known as cleaners. The cleaner concentrate is transferred to a flotation column (4 m diameter and 12 m height), where the final concentrate is obtained. The tailing of the column cell is then combined with the cleaners' feed. The tailing of the cleaner cells is gravity-driven to 5 tank cells, each with a capacity of 50 m³ (RCS 50) to fulfill the scavenging task. The concentrate of this stage is combined with the rougher concentrate and is sent to the regrind circuit. The tailing along with the rougher tailing constitutes the final tailings.

In the flotation circuit of the plant No.2 of the Sarcheshmeh copper complex, without respect to the reagent interactions, usually pH is more than 12 because

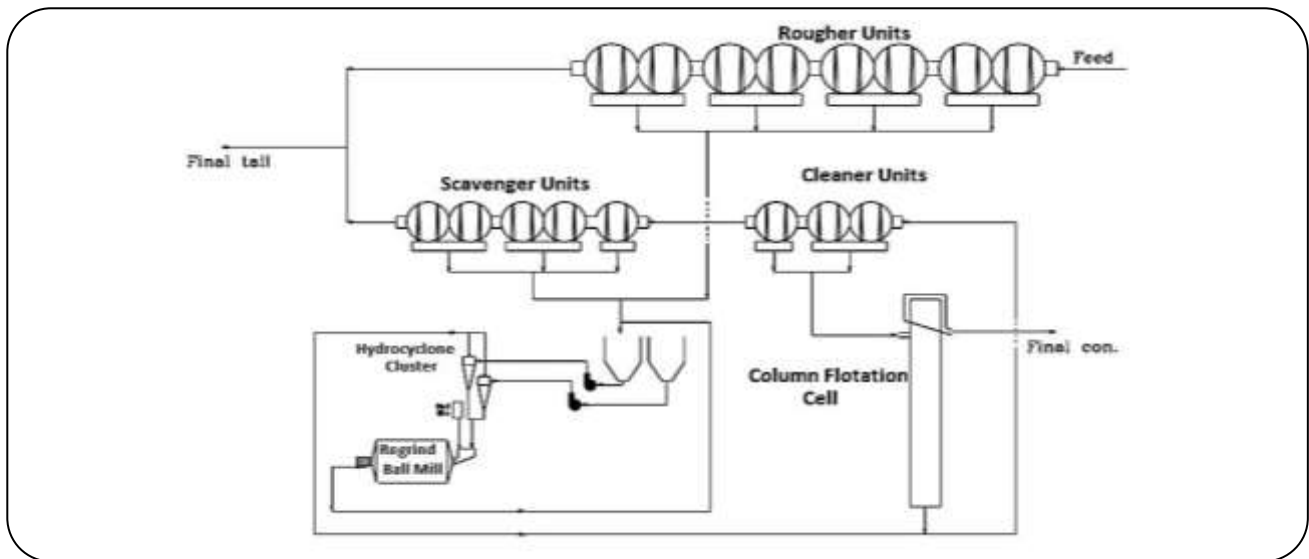


Fig. 3: Flotation circuit of the Sarcheshmeh concentrator No. 2 [22].

of an idea that froth stability is increased at higher pH values. Therefore, determination of the best operation conditions (frother and collector dosages, and pH) at the industrial scale in the circuit are very important and can improve the flotation efficiency levels.

EXPERIMENTAL SECTION

This study was conducted using processing audit [25]. Based on the processing audit, to increase and distribution the reagents, the dosing pumps and pipelines were checked and repaired. Also, new pipelines (to 3rd rougher cell, first scavenger cell, and regrinding ball mill) for reagent addition were installed.

Observation, measurement, recording the non-standard operating behavior, and recording the real plant data for data analysis are some advantages of the process auditing using audit forms. Therefore, an audit form was prepared and the plant data (feed rate, reagent dosage, reagent distribution regime, reagent type, pH, and the active equipment) were recorded daily. Finally, step by step the pH was decreased and the collectors and frothers dosages were increased.

RESULTS AND DISCUSSIONS

The process auditing in a period of 3 months showed that the average of pH in the rougher stage was 12.09, and the average of collectors and frothers dosages were 21.6 g/t (Z11: 75%, and R407 (from the thiophosphates grope): 25%), and 25.1 g/t (Dowfroth250: 60%, and MIBC: 40%),

respectively. However, based on the initial design, the pH in the rougher stage must be 11.5, and the collectors and frothers dosage must be 86, and 154 g/t, respectively. Also, the process monitoring showed that because of the interactions between pH, reagent dosage, and froth stability, an immediate change in the operating conditions (pH, and reagents dosages) are not possible and will decrease the copper recovery. Therefore, step by step the pH was decreased to 11.2 and the reagents dosages were increased to about 35 g/t. Also, the circuit recovery in each step was determined. It must be noted that the circuit became unstable with further changes in the pH and reagent dosages.

The effects of pH on the copper recovery

The effect of pH on the copper recovery was investigated in a period of 40 days. The results showed an increase in the copper recovery by decreasing the pH from 12 to 11.5 and with further reduction, the copper recovery was also decreased (Fig. 4). Hence, as shown in Fig. 4, the best pH range is 11.5-11.7, and with decreasing the pH from 12.09 (average of pH in the rougher stage) to about 11.6, the copper recovery is increased about 1%. Also, the lime dosage was dramatically decreased from approximately 5 to approximately 3.5 kg/t.

The effects of the reagent dosage on the copper recovery

In the circuit, simultaneous with each reduction step in pH, an increasing step in the reagents' dosages were

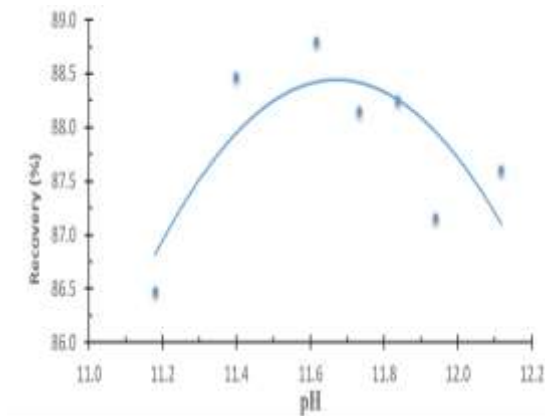


Fig. 4: Effect of pH on the copper recovery at the flotation circuit of the Sarcheshmeh concentrator No. 2.

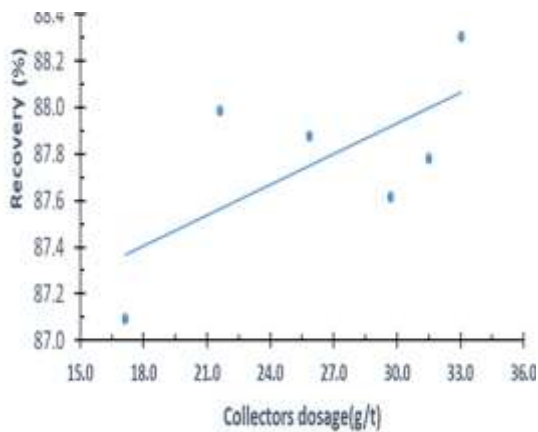


Fig. 5: Effect of collector dosages on the copper recovery at the flotation circuit of the Sarcheshmeh concentrator No. 2.

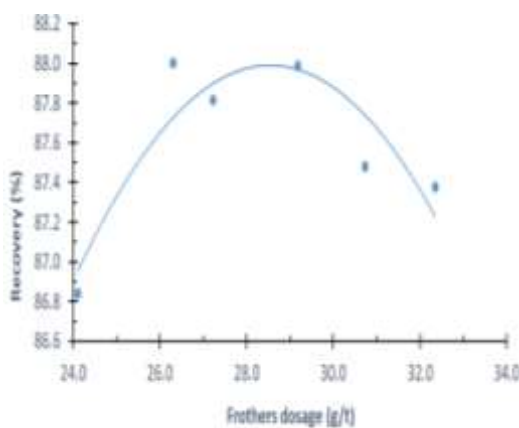


Fig. 6: The effects of the frother dosage on the copper recovery at the flotation circuit of the Sarcheshmeh concentrator No. 2.

performed. Finally, the collectors and the frothers dosages were increased from 21.6 and 25.1 g/t to about 35 g/t. The results showed that the copper recovery is increased about 0.05% by an increase of about 1 g/t in the collectors' dosages (Fig. 5).

Also, the results showed that the copper recovery is maximized by increasing the frothers dosages to about 29 g/t, and with further increasing the copper recovery was decreased (Fig. 6). Furthermore, by increasing the frothers dosages from 25.1 to the range of 27-30 g/t, the copper recovery was increased about 1 %.

The effects of the modifications on the circuit copper recovery

Based on the results and with respect to the reagents interactions, for assessing the effects of all changes on the copper recovery, in a period of 40 days, the pH was set at 11.7 and the collectors and frothers dosages were set at 29.1 and 31.2 g/t, respectively. Also, due to the effects of reagent distribution regime on the Sarcheshmeh flotation performance [9], 75% of the reagents were added before the rougher stage (in the ball mills), and the remaining 25% was added in the third rougher cell. Also, the results showed that because of the modifications in the pH, reagents dosages, and distribution regime, the copper recovery was increased about 2% (Fig. 7). In addition, the results showed that by increasing the final copper grade, the effects of modifications on the copper recovery will be also increase (Fig. 7).

Finally, in this research, in the industrial scale, based on the maximum recovery, the best pH, collectors, and frothers dosages at the flotation circuit of the Sarcheshmeh copper complex were about 11.7, 29.1 g/t, and 31.2 g/t, respectively.

CONCLUSIONS

- The process audit showed that the pH in the rougher cells of the Sarcheshmeh copper complex was over 12, while based on the initial design it must be 11.5.

- By decreasing the pH in the flotation circuit of the Sarcheshmeh copper complex from 12.09 to the range of 11.5-11.7, the copper recovery was increased about 1%.

- In the flotation circuit of the Sarcheshmeh copper complex by increasing 1 g/t of collectors' dosages (in the range of 18-33 g/t), the copper recovery was increased about 0.05%.

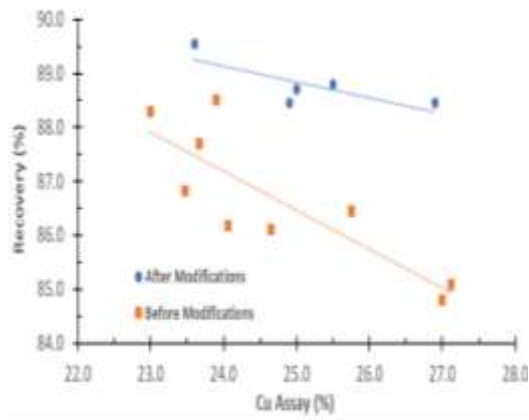


Fig. 7: Effect of modifications on the copper grade and recovery.

- The best frothers dosages range for the maximization of copper recovery in the flotation circuit of the Sarcheshmeh copper complex was 27-30 g/t.

- The results showed that by modifications (reduction of pH to 11.7, increasing the collectors and frothers dosages from 21.6, and 25.1 to 29.1, and 31.2 g/t, respectively, and change in the reagent distribution regime), the copper recovery was increased about 2%.

- Finally, in this research, in the industrial scale, based on the maximum recovery, the best pH, collectors, and frothers dosages at the flotation circuit of the Sarcheshmeh copper complex were about 11.7, 29.1 g/t, and 31.2 g/t, respectively.

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