

Research Article

The Role of pH and Solid Content of Ball Grinding Environment on Rougher Flotation

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Abstract: The purpose of this study was to investigate the influence of grinding pulp pH and solid content on the performance of rougher flotation of Sarcheshmeh copper sulphide ore by a series of batch flotation tests. The results indicated that pH and solid percentage had extremely significant effect on recovery and grade of copper. Copper recovery of rougher cells strongly increased with increasing the pH and solid content, while as expected copper grade of rougher flotation reduced. In addition, the results demonstrated that maximum separation efficiencies are obtained in solid percentage, 55 and pH, 8, respectively. Finally, regression equations were proposed for correlation between recovery and grad of Cu with pH and solid content of grinding slurry.

Keywords: Flotation, grade, grinding, recovery, sulphide ore

INTRODUCTION

One of the basic operations in minerals processing is grinding of the ore to the point where valuable minerals are liberated from the host rock. Subsequent operations then separate the desirable minerals from the gangue or waste. Grinding is essential to the efficient separation of minerals, is the key to good minerals processing. To produce clean concentrates it is necessary to grind the ore fine enough to liberate the minerals, but over grinding inflates energy costs and can lead to the production of untreatable fine slimes particles (Moema *et al.*, 2009). Ball mills are the most common and versatile type of grinding mills which consists of a rotating cylindrical drum (with lids) with grinding media such as balls (Mori *et al.*, 2004). The ball grinding process inevitably involves contact of the ore (minerals) with the surface of grinding device and the grinding medium. This not only causes wear, but also contamination of the ore with wear debris as well as with precipitated species on the ore surfaces, which this is often deleterious to copper flotation (Wang and Xie, 1990; Yelloji Rao and Natarajan, 1990; Wei and Sandenbergh, 2007; Peng *et al.*, 2003a, b; Greet, 2008; Grano, 2009; Maksimainen *et al.*, 2010; Bruckard *et al.*, 2011).

Flotation is an important and versatile mineral processing step used to achieve selective separation of valuable mineral species from gangue minerals. It utilizes the hydrophobic (aerophilic) nature of mineral surfaces and their propensity to attach to rising air bubbles in a water-ore pulp as the basis for separation

(Biswas and Davenport, 1994). Wet grinding in ball mills followed by flotation is the general practice employed in the beneficiation of copper sulphide ores in which the major minerals of commercial significance typically are chalcopyrite (CuFeS_2), bornite (Cu_2FeS_4), covellite (CuS) and chalcocite (Cu_2S) (Bruckard *et al.*, 2011).

In the last 10 years the importance of grinding mills in preparation of suitable surface chemistry for the downstream operation has been recognized. Some recent studies have demonstrated that different particle breakage mechanisms in grinding mills may change mineral surface properties in different ways, which leads to different mineral floatability (Peng and Grano, 2010).

The importance of the grinding environment on the flotation behaviour of sulphide minerals and ores has been known for many years (Rey and Formanek, 1960). It has been widely accepted that the grinding environment of sulfide minerals such as pyrite, arsenopyrite, chalcopyrite, galena, pyrrhotite and sphalerite has a pronounced effect on the recovery and selectivity of sulphide minerals (Pozzo and Iwasaki, 1989; Wang and Xie, 1990; Yelloji Rao and Natarajan, 1990; Wei and Sandenbergh, 2007; Peng *et al.*, 2003a; Peng *et al.*, 2003b; Huang and Grano, 2005, 2006; Greet, 2008; Grano, 2009; Maksimainen *et al.*, 2010; Peng and Grano, 2010; Bruckard *et al.*, 2011). Therefore this study was aimed to investigate the role grinding pH and solid content on grade and recovery of copper in rougher flotation process.

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This study was carried out on the Sarcheshmeh porphyry copper sulphide ore. The Sarcheshmeh copper ore is largest producing copper plant in Iran which is located body in Kerman province, at 60 km distance of the Rafsanjan city.

MATERIALS AND METHODS

Materials: In order to conduct the experiments, it is essential to prepare the required samples. The obtained samples from the ball mills input of the Sarcheshmeh copper mine were crushed in a jaw crusher. The size fraction of -10+60 mesh was collected for experiments. Samples was then homogenized and sealed in polyethylene bags. Representative samples were chemically analyzed which their chemical analysis presented in Table 1.

Sodium hydroxide was used as pH modifier to maintain the pH at the targeted value during grinding. Lime (CaO) was also used as modifier of pH in flotation process.

Z11 (sodium isopropyl xanthate) and mercaptobenzothiazole were used as collector and MIBC (methyl isoboutyl carbinol) and A65 (polypropylene glycol) were applied as frother.

Grinding: In order to study the influence of solid content and pH of grinding pulp on flotation efficiency, grinding experiments were conducted on representative samples of sarcheshmeh copper ore by a laboratory ball mill (the standard bond ball mill). One thousand four hundred and sixty, gram representative samples were used for grinding experiments. Samples were ground with 20 kg ball in mixing of 12.7, 19.05 and 25.4 mm, respectively in diameter by steel balls such as 70% of particles were finer than 75 micron in diameter. Also, grinding time was 12.5 min.

Flotation: After grinding, the pulp was transferred to a 3 L flotation cell. Flotation tests were conducted using a Denver flotation machine with animpeller speed of 1400 rpm. The percentage solids of was adjusted to 28% at the beginning of each test. The slurry pH was set to be 12, which CaO was used for adjusting pH. Then 40 g/t collectors of Z11 (15 g/t) and mercaptobenzothiazole (25 g/t) were added to the cell and after 1 min, 30 g/t frothers of MIBC (15 g/t) and A65 (Polypropylene glycol) (15 g/t) were added to the cell and finally after 2 min, air was opened and flowed inside the cell and the collecting of the froth was started. The concentrate froth samples were collected at the intervals of 1, 2, 3, 5, 9 and 13 min, respectively. The flotation froth was scraped every 10 sec. Finally, the concentrate and tailing samples were filtered, dried and assayed.

RESULTS AND DISCUSSION

Since the recovery at the rougher stage has a significant effect on the overall copper recovery, because influence of grinding environment on this section was investigated.

Based on the experiments described above, the effect of grinding pH on efficiency of rougher flotation (copper recovery and grade) presented in Fig. 1 and 2. Recovery of Cu was calculated using the following formula:

$$Recovery = \frac{Cc}{(C + T) \times f} \times 100 \tag{1}$$

where,

R = % recovery of Cu

C = Dry weight of concentrate

c = % grade of concentrate

T = Dry weight of tailing and f is % grade feed

Table 1: Chemical analysis of the sarcheshmeh ore sample (Wt %)

Element	Cu	Fe	Mo	S	SiO ₂	Al ₂ O ₃
Weight, %	0.72	5.19	0.035	3.36	55.83	13.32

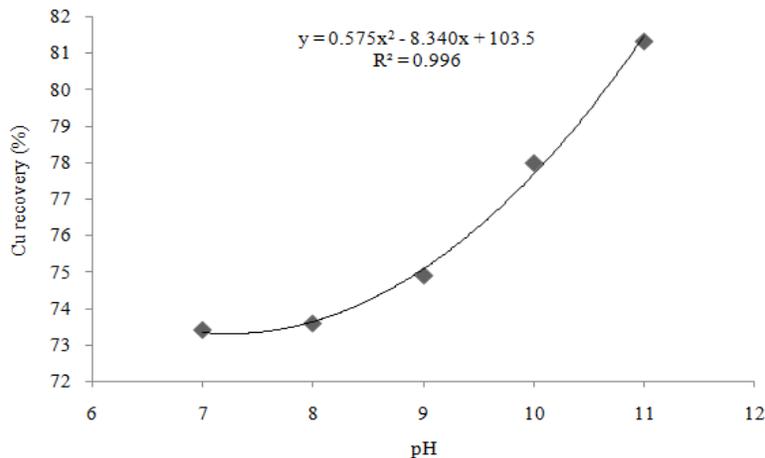


Fig. 1: The effect of grinding pH on the recovery of copper of rougher flotation

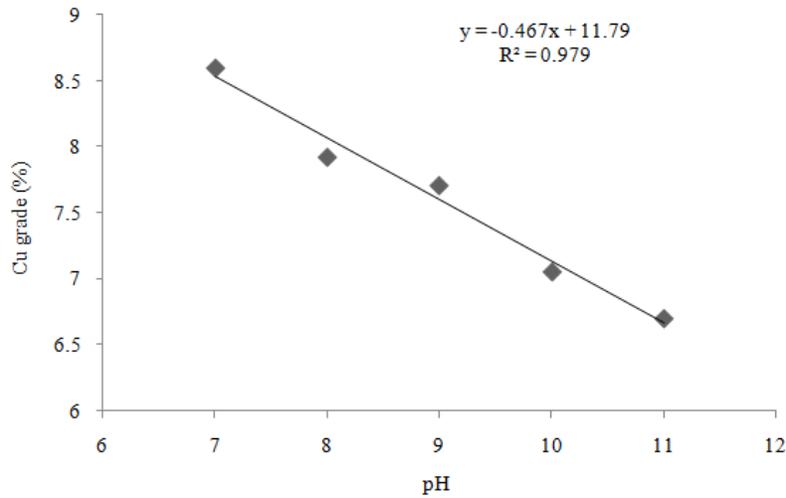


Fig. 2: The effect of grinding pH on the grade of copper of rougher flotation

Figure 1 and 2 indicate the grinding pH influence on recovery and grade of Cu. The pulp pHs of grinding were varied in range 7 to 11 by sodium hydroxide and other grinding condition were fixed in solid percentage, 35, grinding time, 12.5 min and rotation speed of mill, 75 rpm. As can be seen in Fig. 1 and 2, the recovery and grade is significantly affected by pulp pH of grinding. It is seen that higher pH results in smaller grade and larger recovery. This may be caused by the fact that high pH led to formation of iron salt precipitates and consequently passive film on surface of particles. Because sulphide minerals are semiconductors with variable electrochemical properties, which during wet grinding process due to sulphide mineral electrical conductivity occurs a contact between mineral in ore and steel balls that led to a galvanic couple between the balls and the sulphide mineral. As mentioned in literature, this increases dissolution of ferrous ions from steel balls, which are usually precipitate in the form of iron oxy-hydroxides on the surfaces of the sulphide minerals which this affected flotation process. Statistically, according experiments the recovery and grade could be related to the pulp pH of grinding by the regression Eq. (2) and (3), respectively:

$$y = 0.5757x^2 - 8.3409x + 103.52, R^2 = 0.9967 \quad (2)$$

$$y = -0.467x + 11.799, R^2 = 0.9793 \quad (3)$$

The influence of solid content of ball grinding environment on the recovery and grade of copper were investigated by varying the solid percentage in range of 30 to 65. All of experiments were carried out in pH, 7, grinding time, 12.5 min and rotation speed of mill, 75 rpm. Figure 3 and 4 indicated the effect of solid content on Cu recovery and grade. As considered, the increase

of solid percentage strongly affects rougher flotation efficiency with increasing the recovery and reducing the grade. It is obvious that there is a linear relationship between the copper recovery and the solid percentage Eq. (4). In addition grade is related to solid % by a quadratic regression Eq. (5):

$$Y = 0.4318x + 55.763 \leftrightarrow R^2 = 0.9828 \quad (4)$$

$$Y = 0.0023x^2 - 0.2877x + 16.08 \leftrightarrow R^2 = 0.951 \quad (5)$$

In order to determine the optimum condition of experiments (the best combination of grade and recovery), metallurgical separation efficiency of copper was obtained using the following equation (Wills and Napier-Munn, 2006):

$$S.E = R_m - R_g = \frac{100C(c-f)m}{F(m-f)f} \quad (6)$$

where, S.E is Separation Efficiency, m is the percentage metal content of the valuable mineral, F (dry weight of feed) is (C+T), R_m is % recovery of the valuable mineral which obtained from Eq. (1) and R_g is % recovery of the gangue into the concentrate. Recovery of the gangue into the concentrate is calculated from the following formula:

$$R_g = \frac{100C(m-c)}{F(m-f)} \quad (7)$$

According to the conducted experiment, for pHs investigated maximum separation efficiency was obtained 74.52% in pH 8 while for percent solids, maximum efficiency was measured 76.39 in solid percentage 55.

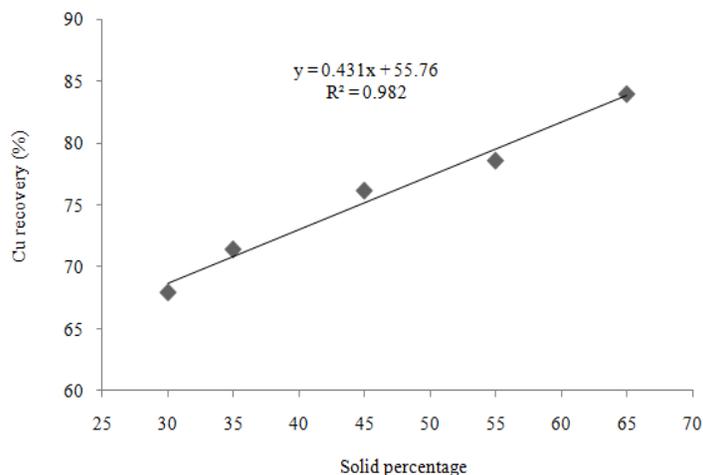


Fig. 3: The effect of solid content of grinding on the recovery of copper of rougher flotation

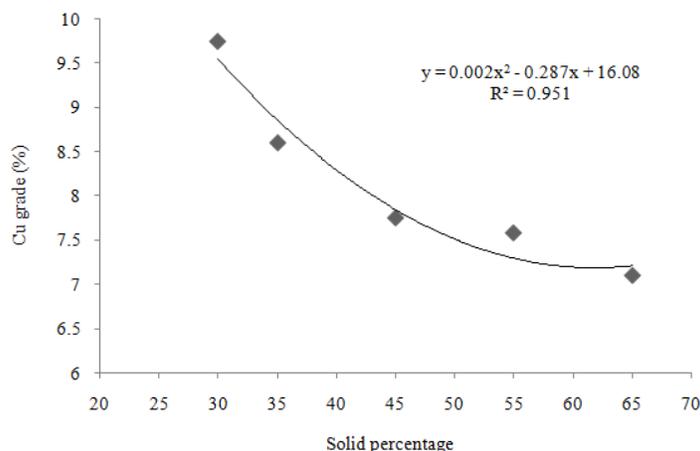


Fig. 4: The effect of solid content of grinding on the grade of copper of rougher flotation

CONCLUSION

This study was aimed to investigate the role of pH and solid percentage of milling environment on rougher flotation efficiency of Sarcheshmeh porphyry copper supplied ore. Grade, recovery and metallurgical separation efficiency of copper were applied to evaluation flotation efficiency. The conclusions based on this research work indicated that pH and solid percentage of slurry of grinding strongly affected flotation efficiency. Increasing the pH in the range investigated had quadratic effect on the recovery of Cu and linear effect on grade of Cu, while solid percentage had a linear effect on grade and a quadratic effect on recovery. In addition, maximum separation efficiency were obtained when grinding experimental conditions included pH, 7 solid percentage, 55%, grinding time, 12.5 min, rotation speed, 75. Finally, results show that recovery of Cu correlated with pH and solid percentage of grinding pulp by regression equations, $y = 0.5757x^2 - 8.3409x + 103.52$ and $y = 0.4318x + 55.763$, respectively. Grade of Cu correlated with pH and solid percentage by regression equations, $y = 0.467x +$

11.799 and $y = 0.00238x^2 - 0.2877x + 16.08$, respectively.

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