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Research article

Granules strength and chloridizing roasting of tailing concentrate at Zhezkazgan concentrator

Yun A., Zakharyan S., Chen V., Terentyeva I., Karimova L.

KazGidroMed LLP, Republic of Kazakhstan, 100009 Karaganda, Erubaev street 51/1

Phone and fax: +7 (7212) 908885, 908882

E-mail: Irina_ter64@mail.ru

Abstract

The study has been performed on preparation conditions of sulphide copper concentrate from concentrator tailings. It is determined that when concentrate is pelletized with saturated solution of sodium chloride the medium size granules (7.5 mm) may stand a layer height up to 9mm.
The laboratory study on chloridizing roasting showed that the maximum extraction of copper and silver into solution is at 97-98 %.

Key words: floatation tailings, pellets strength, roasting, mixing with halite

Introduction

The method of chloridizing roasting is used to convert insoluble precious metal sulphide and oxide into soluble chlorides. The chloridizing is done by adding sodium chloride or chlorine-containing agent to material roasted: for instance sylvinite – a natural compound of potassium chloride and potassium. The chloridizing roasting is used to extract copper and silver from low sulphur feed stock [1].

Materials and Method

This study [2] describes reactions during low temperature roasting of sulphide copper concentrate and potassium and sodium chlorides.

We have studied the pre-optimization of concentrate chloridizing roasting process parameters after the second treatment of mill tailing at Zhezkazgan Concentrator (ZC). The crude float concentrate was used for this study (Table 1).

Table1: Content of crude concentrate basic components %

Cu	S	Fe	Ca	SiO_2	Al	Zn	Ag g/t	Ti	Mg	K	Cl	Pb
0.82	2.0	4.69	3.55	61.05	2.83	0.117	21.8	0.275	0.786	1.48	0.02	0.118

Oxidative chloridizing roasting reactions as follows:

$$Cu_2S_s + 2NaCl_s = 2CuCl_l + Na_2S_s; \quad (1)$$

$$FeS_s + 2NaCl_s = FeCl_2 + Na_2S; \quad (2)$$

$$Ag_2S_s + 2NaCl_s = 2AgCl_s + Na_2S_s; \quad (3)$$

The sodium sulphide generated during chlorination is oxidized by the atmospheric oxygen accompanied by the release of heat as the result of energy-releasing reaction:

$$Na_2S_s + 2O_{2g} = Na_2SO_{4s}.$$

Thus, all reactions during the chloridizing roasting are:

$$Cu_2S_s + 2NaCl_s + 2O_{2g} = 2CuCl_l + Na_2SO_{4s};$$

$$FeS_s + 2NaCl_s + 2O_{2g} = FeCl_2 + Na_2SO_4;$$

$$Ag_2S_s + 2NaCl_s + 2O_{2g} = 2AgCl_s + Na_2SO_{4s}.$$

Due to the atomic weight of copper 63,6 g and the molecular weight of *NaCl* (23+34,5) = 57,5 g and in accordance with reaction (1) the stoichiometric consumption of *NaCl* per each atom of copper will be 57,5/63,6 = 0.904, or 0,904 % per percentage of copper in concentrate.

Due to the atomic weight of iron 55,9 g and in accordance with reaction (2) the stoichiometric consumption of sodium chloride will be 2·57,5/55,9 = 2,06 or 2,06 % per percentage of iron. Therefore, if iron/copper ratio is constant in such crude concentrates. Referring to given above, if iron/copper content ratio in such crude concentrates is assumed constant, then based on that ratio i.e. 4,69/0,82 = 5,72 we will get the total stoichiometric consumption of sodium chloride in terms of copper content in concentrate.

$$\beta_{NaCl} = (0{,}904 + 2{,}06 \cdot 5{,}72)\beta_{Cu} = 12{,}687\beta_{Cu}, \quad (4)$$

Where β_{NaCl} – stoichiometric (required) consumption of sodium chloride, as percentage of concentrate (%); β_{Cu} – copper content in concentrate, %.

Calculation by this formula gives β_{NaCl} = 12,687·0,82 = 10,4 %. That's why concentrate mixing with halite was not with water but the saturated solution of sodium chloride.

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The concentrate was pelletized in the large-sized laboratory pelletizer: pan diameter 1,2m, skirt height 15cm, at 20 RPM, with spraying pelletizing and cubing binder on the mixture. 3% sodium chloride solution was used as the binder. +5-10 mm granules were screened.

The maximum relative loss in weight (W_{105}) of granules (diameter +5-10 mm (average 8 mm)) was 9,79% during drying at 105 ^{0}C which was performed until granules weight change stopped. Bulk weight of wet granules was 1,135 g/cm^3.

In order to choose the optimal design features for transportation or to specify requirement to clum strength for the furnace feed system chosen, it is very important during the preparation process to have granules which strength will allow sustaining loads during transportation and overloading, and during roasting in the furnace. Excess of small particulars decreases gas permeability and increases dust loss and leads to physical loss of feedstock.

During each independent test by means of load fixing 25 granules were chosen to determine unfractured granules output. The results of static and dynamic strength (shock) of granules are given in Table 3.

The static strength or as unfractured granules (unit fraction) was calculated by stochastic strength formula [3]

$$P_c = 0.5^{\left(\frac{2m_G g}{\pi d \rho_c}\right)^6}, \qquad (5)$$

$$P_y = 0.5^{\left(\frac{2mgh}{\pi d^2 \rho_y}\right)^6}. \qquad (6)$$

Where P_c is an output of undamaged granules under the static load (unit fraction), m_G – load force applied, H; g – gravity acceleration, m/s; d – granule size (diameter), mm, ρ_C – effective surface tension under the static load, N/m=J/m^2, P_y – unfractured granules output under the impact load (shock resistance), s.u.; h – height of granules fall, m; ρ_y – fracture surface energy of granule under the impact load, J/m^2.

In order to determine the surface tension under the static load the formula was used, the inverse to (5)

$$\rho_c = \frac{2m_G g}{\pi d}\left(\frac{\ln 0{,}5}{\ln P_c^э}\right)^{1/6}, \qquad (7)$$

It should be noted that granules resisted more to failing or fracturing under the static load than the impact one which is more damaging, therefore, these features were separately determined during testing. For this purpose the formula (6) was used (6), relatively addressed to ρ_y form:

$$\rho_y = \frac{2d\gamma gh}{\pi}\left(\frac{\ln 0{,}5}{\ln P_y}\right)^{1/6}, \qquad (8)$$

To recheck adequacy a nonlinear multiple correlation factor R [4] and its value t_R[5] were used as follows:

$$R = \sqrt{1 - \frac{(n-1)\sum_{i=1}^{n}(y_{э,i} - y_{p,i})^2}{(n-k-1)\sum_{i=1}^{n}(y_{э,i} - \overline{y}_{э,cp})^2}},$$

$$t_R = \frac{R\sqrt{n-k-1}}{1-R^2} > 2,$$

Where, $y_{э,I}$ is a test value; $y_{p,i}$– estimated value; $y_{э,cp}$ – average test value; n – number of independent test data (non-repeated); k – number of operative factor; $(n-1)$ – number of degree of freedom for error mean square; $(n-k-1)$ – number of degree of freedom for dispersion of adequacy.

The formula (5) and (6) were based on probable failure behavior under any load (static, impact, thermal), and as result of it the failure probability is associated with failed material and the intactness probability with unfractured material. The physics of energetic stochastic strength is directly connected with new generated fracture surface energy (J/m^2) or identically equal surface tension (N/m). This energy is counteracted by the relevant load energy and their ratio determines increase or decrease of fractured or unfractured granules output.

The results are given in Tables 2, 3.

0,5-2,3 kg weights were used as the impact load, therefore, the force impact is determined by

$$G = m_G g, H.$$

Table 2: Test results for features determination of effective surface tension ρ_c (H/m) or fracture surface energy (J/m^2) and the static strength of wet granules P_c

m_G, kg	$P^э_c$, s.u.	$P^э_c$, %	$\rho^э_c$ (3)	P_c(1), s.u.
0.5	0.96	96	626.73	0.9985
0.895	0.84	84	880.733	0.9537
1.148	0.68	68	989.692	0.8098
1.922	0.4	40	1434.41	0.0096
2.317	0.16	16	1540.55	0

Table 3: Test results for features determination of effective surface tension ρ_y (H/m) or the fracture surface energy (J/m^2) and the dynamic strength of wet granules P_y (s.u.)

h, м	$P^э_y$, s.u.	$P^э_y$, %	$\rho^э_y$ (4)	$P^э_y$, s.u.	$P^э_y$, %
3	0.88	88	211.72	0.88	88
4	0.32	32	196.04	0.51	51
5	0.24	24	236.03	0.08	8

The average values of static ρ_c and dynamic ρ_y were 1094.42 J/m^2 and 214.6 J/m^2 accordingly.

Highly significant correlation factors between the static and dynamic strength of granules were R=0.86, t_R =9.3>2 and R=0.78, t_R =3.2>2 accordingly and it gives right to utilize the stochastic energetic models of granules strength obtained to estimate the permissible height of a feeder for loading and storage of different size granules of crude copper concentrate.

Table 4 shows the estimation results of granules intactness under the static load in the feeder by changing layer height, granules size as follows

$$P_c = 0.5^{\left(\frac{2d\gamma gh_c}{\pi\rho_c}\right)^6} = 0.5^{\left(\frac{2d\cdot 11359,82h_c}{\pi 1094,42}\right)^6} = 0.5^{(6,4834dh_c)^6} . \quad (9)$$

Table 4: Dependence of granules intactness due to diameter and layer height %

Average *d*, mm	*d*, m	P_c at h_c										
		1	2	3	3,5	4	5	6	6,5	7	8	9
5	0.005	1	1	1	1	1	1	1	0.9999	0.9999	0.9998	0.9996
7.5	0.0075	1	1	1	1	1	0.9999	0.9996	0.9993	0.9989	0.9976	0.9951
10	0.010	1	1	1	0.9999	0.9998	0.9992	0.9976	0.9961	0.9939	0.9866	0.9729
12	0.012	1	1	0.9999	0.9997	0.9994	0.9976	0.9928	0.9884	0.982	0.9604	0.9213
15	0.015	1	1	0.9996	0.9989	0.9976	0.9909	0.9729	0.9566	0.9331	0.8571	0.7316

Table 4 shows that +5-10 mm granules (average 7.5 mm) pelletized with the saturated solution of sodium chloride may sustain level height up to 9 m.

For bigger granules, they significantly fracture if layer height exceeds 3 m, and at 6m the biggest ones will totally fracture. Perhaps, it may be considered as a positive factor as granules fracture to pieces which size equals to optimal size fraction and no designated crushing device is needed.

It should be more clearly noticed when bigger granules fall from different height primarily during loading the feeder as the energetic strength under impact is weaker than under the static load.

Table 5 shows the estimation results of granules intactness under the impact load by formula (4) as follows

$$P_y = 0.5^{\left(\frac{2d\gamma gh}{\pi\rho_y}\right)^6} = 0.5^{\left(\frac{2d\cdot 11359.82h}{\pi\cdot 214,6}\right)^6} = 0.5^{(33.401dh)^6} . \quad (10)$$

Table 5: Dependence of wet granules intactness due to diameter, fall height by formula (10) in %

d, m	P_c (%) at h_c, m					
	1	2	3	4	5	6
0.005	1	0.9991	0.9897	0.9435	0.8011	0.5157
0.0075	0.9998	0.9897	0.8888	0.5157	0.08	0.0005
0.010	0.9991	0.9435	0.5157	0.0242	0	0
0.012	0.9973	0.8406	0.1384	0	0	0
0.015	0.9897	0.5157	0.0005	0	0	0

As it is seen that 7.5mm granules falling from 3m are fractured to 20 %, and from 4 m the same size granules are fractured to 50 %. Therefore, fall height for the feeder charging or loading should not be more than 3 m.

The granules were roasted in the laboratory mill furnace. The temperature and roasting duration effect on copper and silver extraction to solution was studied (Table 6).

Table 6: Effect of roasting temperature (at NaCl consumption - 25% of concentrate weight)

t ^{0}C	Cake output,%	β_{Ag}, g/t in roasted product	β_{Ag}, g/t in cake	ε_{Ag}, %	β_{Cu},%, in roasted product, %	β_{Cu},%, in cake	ε_{Cu}, %
300	43.5	17.4	2.74	93.15	0.66	0.786	48.22
400	42.5	17.4	0.43	98.94	0.66	0.143	90.82
450	35.9	17.4	0.50	98.96	0.66	0.023	98.76
500	35.9	17.4	0.73	98.5	0.66	0.023	98.76
600	40	17.4	0.45	98.96	0.66	0.024	98.54
700	43.5	17.4	0.50	98.75	0.66	0.027	98.2

As this table shows the best results were at 450 0C which is quite comparable to the reference literature.

The duration of roasting has been studied (at consumption NaCl - 25% of concentrate weight and at 450 0C). The results are given in Table 7.

Table 7: Effect of roasting duration on silver and copper extraction into solution

Roasting time, min	Cake output, %	β_{Ag}, g/t in roasted product	β_{Ag}, g/t in cake	ε_{Ag}, %	β_{Cu} in roasted product, %	β_{Cu},%, in cake	ε_{Cu}, %
30	48	17.4	0.63	98.26	0.66	0.075	94.58
45	45	17.4	0.62	98.39	0.66	0.072	95.1
60	42,5	17.4	0.43	98.96	0.66	0.011	99.3
120	42	17.4	0.25	99.4	0.66	0.008	99.47

As it shows the roasting duration equal to one hour is sufficient.

Conclusions

1. Based on the theory of stochastic energetic the granules integrity of crude concentrate has been studied under the static and dynamic loads in the feeder and the reactor. According to the calculation results of granules integrity under the static load in the feeder by changing layer height, granule size (average 7.5mm) the granules pelletized with the saturated sodium chloride solution may remain unchanged if layer height is up to 9 m. It is been determined that the integrity of 7.5 mm granules is at least 80% when the drop height is not more than 3 meters.

2. The chloridizing roasting results showed that the roasting should be conducted at 450-600 ^{0}C for 60 minutes. Under this condition silver and copper extraction is up to 98%.

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