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Saydakhmedova L. A. assistant
Khushvaqtova Z. H. laboratory assistant
Navoi State University of Mining and Technologies Uzbekistan,Navoi
Tolibov B. I. Doctor of Technical Sciences, Prof.
Republic of Uzbekistan, Almalyk

REVIEW OF TECHNOLOGIES FOR OXIDATIVE ROASTING OF SULPHIDE GOLD CAKES BY BACTERIAL LEACHING

Abstract: This article presents the results of literature studies on oxidative roasting of sulfide gold cakes. The complex studies carried out and methods developed to improve the extraction of gold from refractory carbonaceous ores and concentrates (oxidative roasting processes, low-temperature roasting, intensive roasting, etc.) containing a carbonaceous component or other refractory compounds are shown. At the same time, there are problems that are important for the science and practice of mining and metallurgical production, which are associated with the quality of oxidative roasting processes: underoxidation of sulfide particles, low degree of desulfurization, energy loss in processes, etc. This article is devoted to solving these problems regarding the rational use of energy in oxidative roasting furnaces and improving the degree of desulfurization.

Key words: oxidative roasting, fluidized bed furnace, bioleaching cake, suspension roasting.

ОБЗОР ТЕХНОЛОГИЙ ОКИСЛИТЕЛЬНОГО ОБЖИГА СУЛЬФИДНЫХ ЗОЛОТЫХ КЕКОВ ПУТЕМ БАКТЕРИАЛЬНОГО ВЫЩЕЛАЧИВАНИЯ

Аннотация: В статье представлены результаты литературных исследований по окислительному обжигу сульфидных золотосодержащих кеков. Показаны проведенные комплексные исследования и разработанные методы повышения эффективности извлечения золота из тугоплавких

углеродистых руд и концентратов (процессы окислительного обжига, низкотемпературный обжиг, интенсивный обжиг и др.), содержащих углеродистую составляющую или другие тугоплавкие соединения. Вместе с тем существуют важные для науки и практики горнометаллургического производства проблемы, связанные с качеством процессов окислительного обжига: недоокисление сульфидных частиц, низкая степень десульфурации, потери энергии в процессах и др. Данная статья посвящена решению этих проблем в части рационального использования энергии в печах окислительного обжига и повышения степени десульфурации.
Ключевые слова: окислительный обжиг, печь кипящего слоя, кек биовыщелачивания, суспензионный обжиг.

INTRODUCTION

In metallurgical furnaces, by burning fuel, the process of heating the processed material is realized. The heat transfer mechanism is very complex, since in these devices, unlike heat exchangers, the contribution to the total heat transfer of the radiant (radiation) component is significant. The organization of the movement of the generated flue gases and the use of heat from the exhaust gases, in turn, significantly affects the contribution of the convective component to the total heat transfer. Therefore, the design of metallurgical furnaces involves taking into account the characteristics of the supplied fuel, calculating the combustion process taking into account the hydrodynamics of the movement of flue gases, choosing a furnace design, taking into account the characteristics of fuel-burning devices, etc.

Main part. In his works, M.F. Almeida (Portugal) considers the conditions for roasting sulfide gold ores. The criteria chosen to select the firing conditions for the product were the subsequent cyanidation of gold and silver, and the consumption of sodium cyanide and lime. Thus, some oxidation roasting tests were carried out at 450, 500, 550, 600, 650 and 700 °C, where the product was held for 1 hour. An additional two-stage firing cycle at 500°C for 1/2 hour and 625°C for

1/2 hour was carried out to obtain maximum porosity in the pyrite and arsenopyrite mineralogical structure.

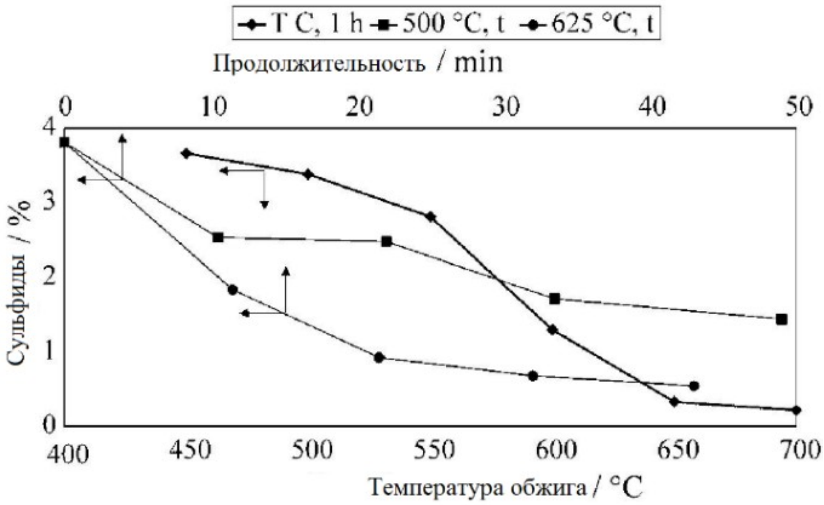

Figure. 1.1 Sulfide content in products under different roasting conditions

Figure 1.1 shows that the sulfur content decreases with increasing firing temperature and time. And the dependence of arsenic was not analyzed, but it should have the meaning since it was sometimes visible as white As_2O_3 even after the roasting process was completed. The product changed to a bloody red color at roasting temperatures above 600°C due to the formation of Fe_2O_3. At a roasting temperature of ≥600 °C, the resulting products were much less acidic than the original ones. Consequently, much less lime is required to obtain the correct alkalinity for cyanidation; conversely, if the product was fired at ≤550°C, the lime required to achieve the correct alkalinity is still high and approximately equal to that required under initial conditions when the firing process was carried out at 450°C. Pre-washing can reduce lime consumption mainly at these lower roasting temperatures. In the gold sulphide concentrate tested, three main causes account for most of the response variability found in the leaching tests: (1) gold exists in the form of free and non-free particles with sizes ranging from <10 μm to >100 μm; (2) the product has completely burnt particles and partially and almost intact sulfide particles; and (3) the particle size distribution of the samples is very different, and gold in the finer fractions is higher than in the coarse ones. As a consequence, the sulphide concentrates samples used in the tests showed noticeable dispersion in gold content. The effect of firing conditions on this product, as assessed by cyanidation experiments performed, was as follows: (1) silver recovery is higher at the lowest firing temperatures in the range of 450-700 °C; (2) lime and NaCN consumption is lower for products fired at higher temperatures in this range; 3) pre-washing fired products reduces the lime needed to adjust the pH of the pulp, mainly for fired products at 550 °C or lower; (4) after calcination of the product for 1 hour at any temperature, in the range of 450-700 °C, it can be said that there is approximately a 93% probability that highly concentrated cyanide solutions will leach at least 74% Au, in 24 hours; 5) there is no evidence that pre-washing the fired products improves gold or silver recovery. To study the processing of sulfide gold ores, there was the Kokpatas deposit, bioleaching cakes of hydrometallurgical production. Samples were taken and a full chemical analysis of the samples was carried out at the Central Research Laboratory of the State Enterprise "NMMC". The results of the analysis are shown in Table 1.1.

Table 1.1

Name	Contents, %								
	SiO_2	Fe_2O_3	FeO	TiO_2	MnO	Al_2O_3	CaO	MgO	Na_2O
sample №1, cake of BIOX	32,5	9,54	2,45	1,65	0,048	8,4	9,18	2,22	0,66
sample №2, cake of BIOX	33,1	9,21	2,34	1,52	0,050	8,7	9,21	2,20	0,59

Continuation of Table 1.1

Name	Contents, %									
	K_2O	P_2O_5	SO_3 общ	П.п.п.	As	SO_3	$S_{сульф.}$	H_2O	Au у.е.	Ag у.е.
sample №1, cake of BIOX	1,9	0,25	31,2	16,5	2,0	13,93	25,63	6,2	29,0	28,0
sample №2, cake of BIOX	1,88	0,28	31,0	16	1,95	14,17	24,45	6,6	28,7	28,1

The chemical composition of samples of sulfide gold ores was studied using the standard silicate method and quantitative X-ray fluorescence analysis performed on a PW - 1404 device from the Dutch company Phillips. The mass fraction of total organic carbon was determined using classical methods of organic geochemistry.

Table 1.2. Chemical composition of ore samples by main components

Components	Mass fraction ,%	Components	Mass fraction ,%	Components	Mass fraction ,%	Components	Mass fraction ,%
SiO_2	39,76	MnO	0,33	$S_{общ.}$	3,84	$C_{орг.}$	0,53
TiO_2	1,74	P_2O_5	0,77	As	2,14	$C_{карб.}$	2.32
$A1_2O_3$	13,69	K_2O	3,10	Sb	0,0079	Au, г/т	3,90
$Fe_{общ.}$	7,46	Na_2O	2,27	Cu	0,024	Ag, г/т	5,9
CaO	8,37	MgO	5,67	$C_{общ.}$	2,85.		

From table 1.2. it is clear that in the processed ores of GMZ-3 gold is found mainly in sulfide compounds, both in the form of finely disseminated gold, as well as in the form of carbonaceous compounds that interfere with the sorption cyanidation process. This means that the incoming ore for processing at GMZ-3 is refractory. Several experiments were carried out in laboratory conditions on sulfide biocakes GMZ-3 NMMC, the source of which is refractory gold ores of the Kokpatas and Daugyztau deposits. Experiments were carried out under different conditions to determine the optimal mode of oxidative roasting. The results of the experiments are presented in a diagram. (Look at Figure 1.2.) (T=60 min. τ=600°C). From Figure 1.2 it is possible to determine optimal conditions for intensive firing of sulfides in a fluidized bed furnace. It should be noted that when suppressing the charge (sulfides), if possible, the material should contain a minimum amount of moisture, no more than 5%. The duration of the process is 1-1.5 hours. At a temperature of 600-650°C, depending on the humidity of the material, the degree of desulfurization is up to 98-99% [28; p.583-585].

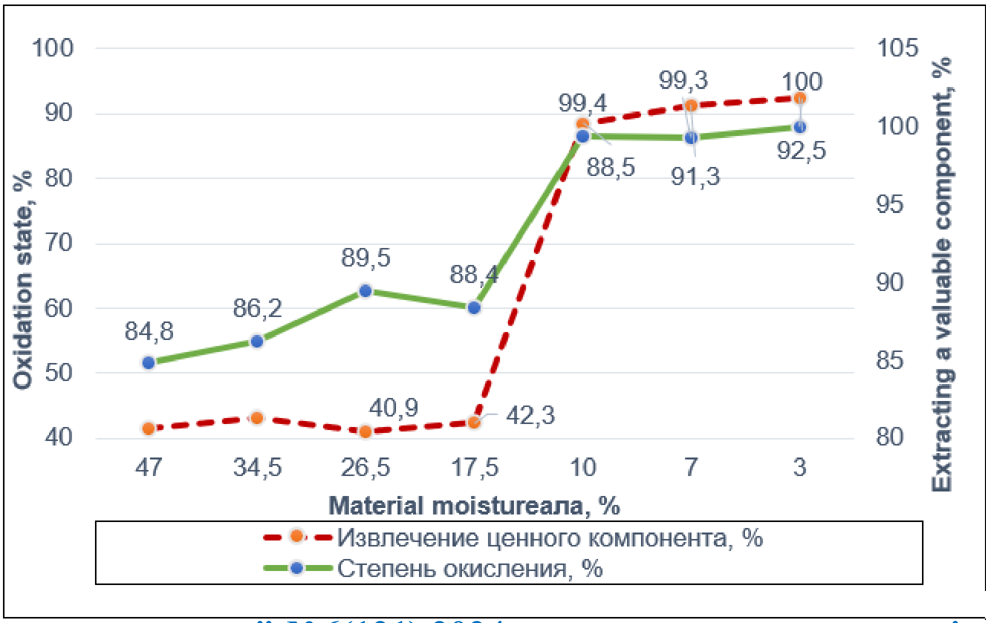

Figure 1.2. Dependence of material moisture on the degree of oxidation and extraction of a valuable component

In Figure 1.2. It has been shown that the degree of oxidation and further the degree of extraction of the valuable component depends on the moisture content of the material supplied to the processing process using oxidative roasting. It should be noted that when the humidity is more than 10%, the supplied material is first dried and then fed into roasting. Therefore, in the graph you can see that the material supplied for firing contains moisture from 17% to 47%, then oxidative firing is almost not observed under such conditions. When conducting research on the roasting process, the following sequence of work on processing sulfur- and carbon-containing difficult-to-process BIOX intermediates was adopted.

1. Foam product from BIOX reactors (S up to 8%, C up to 3%) – 50%.
2. BIOX cake (S up to 6%, C up to 4%) – 50%.

The charge (up to 10 kg/h) consists of the above intermediate products (on average up to 7% S, up to 3% C).

After filtration, the mixture with a moisture content of W = 30-35% is sent to a tubular rotary kiln for drying. Oven temperature 250-300°C. The resulting cake (W=1%) is subjected to low-temperature solid-phase oxidative firing in the proposed furnace. Firing in laboratory conditions is carried out in suspension in a stream of fire in a stationary furnace 600 mm long, 200 mm wide and 400 mm high (see drawing No. 2-201502, stage No. 8), maximum furnace temperature 600-650 °C.

The first zone, where the release of internal and hygroscopic moisture of the material occurs, has a length of 400 mm with T - 400-450 ° C, in the second zone the process of coal combustion and the dissociation of pyrite, pyrrhotite, arsenopyrite with partial oxidation begins. These processes take place in the tail part of the furnace, where the temperature is 550-600°C and the oxidation of sulfur and carbon compounds is completed. The cinder is removed through the hole and washed with a 2% NaOH solution and transferred for further cyanidation (you don’t have to wash it). Sulfide sulfur- and carbon-containing difficult-to-process BIOX intermediates and concentrates are in many cases transferred to oxidative roasting before hydrometallurgical processing. The purpose of oxidative roasting is to remove sulfur and carbon from the material and convert iron sulfide compounds into oxides, and gold into easily cyanidated ones during subsequent processing.

Entering the roasting furnace, the material heats up, receiving heat from the furnace body and hot furnace gases. For oxidation to occur, the material must be heated to the ignition temperature of the main sulfides, and in order to remove sulfur and carbon, natural gas, a mixture of air and dried material (W-1-5%) must be constantly supplied to the flame zone. The ignition temperature is the temperature at which the oxidation of sulfide occurs so intensely that the heat released becomes sufficient for the process to spontaneously spread throughout the entire mass of the material.

The performance of the oxidative roasting process is influenced by the following factors: blast supply speed, oxygen concentration during air suppression, mineralogical composition of the supplied material, process temperature, size of the charge particles and intensity of mixing of the charge in suspension, as well as the temperature of the supplied heated air. During oxidative roasting, the formation of oxides or sulfates occurs through the following reactions:

$$2MeS + 3O_2 = 2MeO + 2SO_2 \qquad (2.1)$$

$$2SO_2 + O_2 = 2SO_3 \qquad (2.2)$$

$$MeO + SO_3 = MeSO_4 \qquad (2.3)$$

The least stable of the metal sulfates are iron sulfates, which noticeably dissociate already at temperatures of 480-520 ° C in the air atmosphere; sulfates are more stable and decompose at temperatures of 650-700°C. Under conditions of increased concentration of sulfur oxides in furnace gases, the firing temperature limit may be slightly increased. Experiments on oxidative roasting of sulfur- and carbon-containing difficult-to-process BIOX intermediates and concentrate (charge) are carried out in a laboratory intensive roasting furnace [81; p.68-85].

Conclusion

Thus, with the use of oxidative roasting, the extraction of gold from sulfide, carbonaceous and arsenide compounds is achieved; approximately 85-90% of sulfide and 80% of carbonaceous compounds are destroyed, the rest of the gold remains in the tailings. The use of the oxidative roasting process in fluidized bed furnaces is most effective for processing refractory gold-bearing cakes, where sulfide particles are oxidized and the cinder turns into a porous mass of oxides that is highly permeable to cyanide solutions.

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