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Application of Energy-Saving Technology in The Smelting of Copper Sulfide Concentrates in Autogenous Processes

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***Abstract**: The article discusses the ways of improving the energy-saving technology for obtaining low-sulfur copper-sulfide concentrates in the production of copper. Research is relevant in the field of non-ferrous metallurgy, in particular, to increase the heat transfer of copper concentrates processed in oxygen-flare furnaces and Vanyukov furnaces. To increase the heat transfer of the concentrate, it is proposed to use pyrite concentrates from the selective flotation process as auxiliary compounds. The heat transfer properties of pure pyrite have been studied by the calorimetric method. The amount of heat generated by the combustion of pyrite was compared with the heat transfer properties of natural gas. Feasibility studies have shown that the use of pyrite concentrate on an industrial scale is cost-effective.*

Keywords— *metallurgy, copper, pyrite, heat, calorimeter, beneficiation, smelting, metallurgical furnace, reaction mechanism, natural gas, fuel***.**

1. Introduction

To date, there are several different methods of processing sulfide copper concentrates. These are: reverberatory furnace, oxygen torches and melting processes in Vanyukov furnaces [1]. The principle of operation of these processes is similar, the main difference is that in the process of refractory smelting copper sulfide concentrates are less oxidized and pass into the iron matte in large quantities. Because there is no oxidizing atmosphere in the reverberatory furnace [2]. Therefore, the average percentage of copper in matte increases only slightly due to lower sulfides formed by the decomposition (desulfurization) of the higher sulfides in the matte. This is a major drawback of the flame retardant process [3].

In the process of oxygen torch smelting, copper sulfide concentrates are processed by oxidative smelting in the presence of technical oxygen (95% oxygen) [4]. In this case, if the content of sulfides in the concentrate is low, and the content of oxide compounds is high, it is impossible to heat the furnace well, because the furnace does not use fuel [5]. This means that the processing of low-sulfur sulfide copper concentrates in an oxygen torch smelting furnace is inefficient [6].

Oxidative smelting is also used in the processing of copper sulfide concentrates in a liquid bath, ie in the Vanyukov furnace, but this process uses external natural gas or fuel oil. The main disadvantage of this process is the high cost of fuel used for smelting [7].

The purpose of the proposed method in the study is to increase the heat transfer capacity of sulfide copper concentrates and save natural resources [8].

2. Materials and Methods

Materials of research are pyrite concentrates and low-sulfur copper concentrates [9]. Pyrite enriches contain a large amount of sulfur, which releases large amounts of heat when exposed to oxygen. The chemical composition of pyrite concentrates is given in Table 1. The content of the mineral pyrite - FeS_2 in such enrichments is about 75% [10]. The calorimetric method of analysis was used to determine the heat transfer properties of pyrite enriches [11].

The calorimetric method of measuring thermal energy is a versatile method that is used for low and high power over the entire radio frequency range [12]. It differs from other methods in that it increases the accuracy of measurements [13]. The calorimetric method of measuring energy is based on the conversion of electromagnetic energy into thermal energy, which then measures the temperature rise of the working medium of the calorimeter, which absorbs this energy [14]. Figure 1 shows a calorimeter device used to measure the heat capacity of substances.

3. Experimental Part

The following sequence of processes was used to achieve the goal of the study [15]:

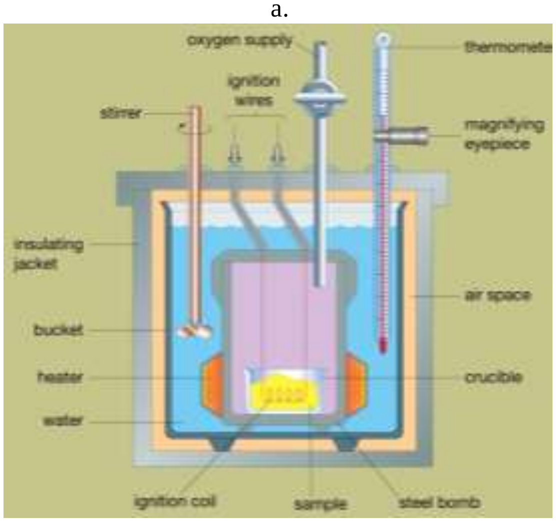
- Initially, a slag was prepared to increase the heat transfer properties of sulfide concentrates. The slag is mixed with ordinary sulfide copper concentrate, flux and pyrite concentrate. As flux, compounds containing large amounts of SiO_2, made from the wastes of gold concentrators, were used as quartz flux, and gypsum compounds from sulfuric acid plants were used as lime flux. As pyrite enriches were used enzymes formed after selective enrichment of sulfides and containing large amounts of pyrite [16]. Their chemical composition is given in Table 1;

- The resulting lime was processed in smelting furnaces, with the use of oxygen torches and Vanyukov furnaces [17].

Table 1: Chemical composition of pyrite enrichment,%

Number of samples	The constituent elements			
	Cu	Fe	S	SiO_2
Sample 1	0,23	37,8	41,7	6,2
Sample 2	0,51	34,5	39,3	10,1
Sample 3	0,82	31,0	40,9	7,6
Number of samples	CaO	Au, g/t	Ag, g/t	Al_2O_3
Sample 1	7,0	0,4	2,0	6,0
Sample 2	9,5	0,4	1,4	5,2
Sample 3	8,1	0,4	1,5	10,57

a.



b.

Fig.1. Calorimeter device for determining the temperature of pyrite concentrates: general appearance of the a-calorimeter, the principle of operation of the b-calorimeter

4. Results and Discussion

This method oxidized pyrite minerals, which contained a large amount of sulfur, and released a large amount of energy, which resulted in the energy required to melt the raw materials of autogenous or semi-autogenous furnaces [18]. It should be noted that although the oxidation of pyrite is an exothermic reaction, its oxidation does not occur under normal conditions. Therefore, it must be heated first, that is, it must provide activation energy. The mechanism of oxidation of pyrite can be thought of as follows:

Initially, when heated, pyrite decomposes to form pyrrhotine and sulfur [19]:

$$FeS_2 \rightarrow FeS + ½S_2 – 70440 \text{ kcal / (kg • mol)}$$

Then, because the sulfur in the system is active, it first reacts with oxygen and oxidizes to SO_2:

$$S+O_2=SO_2 + 70960 \text{ kcal / (kg • mol)}$$

As the sulfur on the reaction surface oxidizes to gas, the next layer of pyrrhotite begins to react with oxygen. The chemical reactions that can occur in a reaction system can be described as follows:

$$2FeS+3O_2 = 2FeO + 2SO_2 +112440 \text{ kcal / (kg • mol)}$$

$$3FeS + 5O_2=Fe_3O_4 + 3SO_2 + 411720 \text{ kcal / (kg • mol)}$$

$$2FeS + 3,5O_2 = Fe_2O_3 + 2SO_2 + 292980 \text{ kcal / (kg • mol)}$$

$$FeS+3Fe_2O_3=7FeO+SO_2+95360 \text{ kcal / (kg • mol)}$$

The above oxidation reactions are intermediate reactions and often stop after the formation of hematite [20]. In general, the oxidation reaction of pyrite to hematite can be described as follows:

$$4FeS_2 + 11O_2 = 2Fe_2O_3 + 8SO_2 + 3309,6 \text{ kJ (791,77 kcal)}$$

Calculations and studies have shown that when 1 kg of pure pyrite is completely oxidized in the presence of oxygen, 6895 kJ (1649.52 kcal) of heat is released. If the heat of combustion of 1 m^3 of natural gas is 8000 kcal (33440 kJ), then to compensate for the heat of combustion of 1 m^3 of natural gas is needed 8000/6895 = 1.16 kg of pure pyrite mineral [14]. Table 2 shows the amount of pyrite concentrate needed to replace the natural gas used to melt 1 ton of shale in a metallurgical furnace. In addition to pyrite, the amount of other additives is taken into account when calculating the consumption of pyrite enrichment. For example, for 1 kg of pure pyrite, the amount of its corresponding enrichment is 1 / 0.75 = 1.333 kg. In this case, 1.16 / 0.75 = 1.55 kg of pyrite enrichment is used to save 1 m^3 of natural gas [21].

At present, the cost of 1 m^3 of natural gas for legal entities is 1,100 Uzbek sum, and the introduction of pyrite enrichment will save 24,200 Uzbek sum from the savings of natural gas used to melt 1 ton of ore [22].

The implementation of this method provides the following benefits:

- during the oxidative melting of sulfide copper concentrate in fully autogenous or semi-autogenous processes, the heat transfer properties of the concentrate increase;
- Pyrite enriches can also be used;
- the possibility of sulfidation of oxidized copper compounds due to sulfur in pyrite concentrates;
- It is possible to separate rare metals such as copper, gold, silver from pyrite enrichment by matte;
- When gold, silver and similar heavy and rare metals melt and mix with matte droplets, the density of matte increases and the rate of transition to the main matte phase increases;

- the addition of pyrite concentrate to the shaft in order to increase its heat transfer capacity allows to save fuel consumption, which is a major part of the cost of finished metal currently produced;
- the economic cost of finished copper, ie the cost of finished copper, is reduced due to the reduction of fuel consumption;
- Involvement of pyrite concentrates in the production will increase the use of non-ferrous metallurgical raw materials;
- leads to a decrease in the content of magnetite (Fe_3O_4), which adversely affects the process of liquid slag;
- When the amount of magnetite in the slag decreases, the liquid level and ductility of the metal immediately increase, and the density and viscosity decrease. This allows the slag and matte phases to separate more quickly;
- due to the decrease in the density and viscosity of the slag, the transition of mechanically mixed matte droplets to the main matte layer immediately increases;
- SO_2 and SO_3 gases from the combustion of sulfur in pyrite enrichment are used to produce sulfuric acid.

Table 2: Comparative analysis of the heat transfer properties of natural gas and pyrite mineral

№	The amount of natural gas saved (%)	The saved volume of natural gas used to melt 1 ton of charge (m^3)
1.	10	20-22
2.	20	40-44
3.	30	60-66
4.	40	80-88
5.	50	100-110
	The amount of natural gas saved (%)	The amount of pyrite used to replace the saved natural gas (kg)
6.	10	31-34
7.	20	62-68
8.	30	93-102
9.	40	124-136
10.	50	155-171

The main disadvantage of this method is that the mass of slag increases slightly due to the oxidation of iron in the pyrite concentrate. However, if excess oxygen is not added to the process, the viscosity and density of the slag will not change. This has almost no negative effect on the process [15].

The difference (novelty) of the method from the analogues and prototype is that pyrite was added to the sulfide copper concentrate in the preparation of the slag before loading the raw material into the furnace, gypsum and gold-bearing quartz ores were used as flux.

Comparison of this study with its analogues showed that the furnace unit heats up slowly due to the fact that less oxidation of copper sulfide concentrates releases less heat. As a result of oxidation of pyrite to copper, the furnace unit heats up faster and the raw material liquefies faster, which means that the activation energy required to start the process is produced faster.

5. Conclusion

Due to the lack of thermal energy in the processing of relatively low-sulfur concentrates in a metallurgical furnace, a study was conducted on the use of pyrite concentrates to overcome this problem. The lack of energy can also be overcome by adding other substances, such as technical sulfur, to the slag. But technical sulfur is more expensive than pyrite enriches. Pyrite concentrates are formed after selective flotation in the enrichment of sulfide concentrates and are considered to be unnecessary rock. This means that pyrite concentrates are extracted as satellite minerals during flotation and are very inexpensive. It is no exaggeration to say that pyrite concentrates are free materials in the concentrators of copper plants. Feasibility studies have shown that the processing of low-sulfur copper concentrates by this method reduces the cost of copper extraction.

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